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The Alaskan Oil Disposition Study Potential Air Quality Impact of a Major Off-Loading Terminal in the Pacific Northwest

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THE ALASKAN OIL DISPOSITION STUDY:
POTENTIAL AIR QUALITY IMPACT OF A MAJOR OFF-LOADING TERMINAL IN THE PACIFIC NORTHWEST

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This study evaluates the air quality impact of a marine oil transfer terminal for Alaskan oil. It includes an evaluation of specified sites with regard to present emissions and air quality; the determination of the potential emissions associated with a major crude oil offloading facility; and a preliminary modeling analysis to assess the potential air quality problems which might be associated with the operation of such a port. Oil transfer facilities of the sizes evaluated in this study have the potential for significantly impacting air quality.

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EXECUTIVE SUMMARY

This study was performed by EPA Region X at the request of the Federal Energy Administration (FEA). The study entails three parts: an evaluation of specified sites with regard to present emissions and air quality; the determination of the potential emissions associated with a major crude oil offloading facility; and a preliminary modeling analysis to assess the potential air quality problems which might be associated with the operation of such a port.

In all, nine sites were evaluated in this study; seven in Washington - Cherry Point (Ferndale), March Point (Anacortes), Burrows Bay, Port Angeles, Offshore Copalis Beach, Copalis Beach and Grays Harbor - and two in Oregon - Offshore Clatsop County and Astoria.

Two basic scenarios were evaluated; the first based on a daily throughput of 1,000,000 barrels, the second based on a daily throughput of 1,350,000 barrels. Scenario I would require 379 port calls annually and eleven 650,000 barrel capacity storage tanks. Scenario II would require 517 port calls annually and fifteen 650,000 barrel storage tanks. In addition, two subscenarios, based on limiting tanker size to less than 125,000 dead weight tons per current Washington State Law, were evaluated. This would increase the annual port calls required to deliver the crude oil to 654 for Scenario I and 1,033 for Scenario II.

Of the nine sites evaluated, six still have relatively clean air and are considered to be in compliance with all federal, state and local ambient air quality standards. Three sites, however, already have significant emission sources and are known or suspected of experiencing violations of applicable ambient standards. These sites are Cherry Point for sulfur dioxide (SO_2), March Point for SO_2 and Port Angeles for SO_2 and total suspended particulates (TSP).

The emissions from the storage tanks were calculated using the American Petroleum Institute method for floating roof tanks. These emissions, when combined with fugitive emissions from other sources such as pump seals, valves and routine spills, result in a range of annual hydrocarbon emissions for storage and transfer operations as shown in the Summary Table. The range of emissions is caused by differences in the average annual wind speeds for the various sites.

The emissions resulting from the combustion of residual oil with a 1.5 percent sulfur content by the tankers were calculated using fuel combustion rates provided to the FEA by oil companies. These calculations revealed that the most significant pollutants from combustion would be SO_2, nitrogen oxides (NO_x) and particulates. The total annual emissions of these pollutants for each scenario are shown on the Summary Table. The use of a residual fuel oil with the more common 2.5 to 3.0 percent sulfur content would as much as double the SO_2 emissions.

There are fugitive hydrocarbon emissions from the tankers which are associated with tanker operations such as fueling, ballasting and purging. In addition there are hydrocarbon emissions which result simply from evaporative venting from the cargo cells. Emissions from refueling with residual oil are insignificant and venting emissions are generally small. However, the emissions associated with ballasting and purging operations are quite significant. The ranges of annual fugitive hydrocarbon emissions from tankers, depending upon whether ballasting or purging occurs in the port vicinity, are shown on the Summary Table. The low end of the range is for no purging or ballasting emissions; the high end includes purging and frequent ballasting emissions.

A model was developed to simulate port operation for a period of ten years to provide the frequency of occurrence of different emission levels. From this, the average and worst case emission rates were determined.

These emissions were then modeled to evaluate the potential for adverse air quality impact as measured by short-term standards (less than 3-hours). The impact of tanker combustion emissions were evaluated by the use of Gaussian point source models such as "PTMAX" and the "EPA Valley model", whereas the fugitive hydrocarbon emissions from the tank farm and tankers were evaluated using a volume source model.

The results of the modeling analysis indicated that tanker combustion emissions have the potential to produce significant short-term SO_2 concentrations, possibly in excess of ambient standards when interaction with elevated terrain becomes a factor (the impact of an elevated source varies with topography). At those sites with existing SO_2 air quality problems, the contribution by a new source of this magnitude would compound the situation and possibly hinder the attainment and maintenance of the standards. Also, the use of a higher sulfur content fuel would increase the probability of standards violations.

The modeling analysis also showed that the short-term NO_x concentrations could be significant although there are currently no short-term NO_x ambient standards which apply. Also, an additional source of particulates in Port Angeles could compound the existing TSP problem and affect attainment of the annual state and local standards.

The modeling of the tanker fugitive hydrocarbon emissions indicated that purging would likely cause massive violations of the Primary National Ambient Air Quality Standards (NAAQS) for hydrocarbons under any meteorological conditions. The modeling also indicated that the hydrocarbon emissions associated with ballasting could result in hydrocarbon concentrations many times in excess of the NAAQS in the vicinity of the berths. In addition, it was found that the evaporative venting emissions alone could possibly produce concentrations in excess of the NAAQS for hydrocarbons for relatively short distances under stable conditions.

The combined hydrocarbon emissions from tankers and tank farm and NO_x emissions from the tankers in conjunction with any existing emissions could create the potential for a photochemical oxidant problem. However, the hydrocarbon/oxidant relationship for the Pacific Northwest environment is not yet well understood and further study would be required to assess the nature and magnitude of any potential problem.

The adverse impact of an off-loading facility could be reduced by the use of several mitigating measures. SO_2 emissions could be reduced by at least a factor of three by the use of low sulfur distillate fuel oil at berth during offloading. Since purging is an optional procedure determined by the tanker master and not currently required for safety, it could be regulated so as not to be permitted at or near the port. Hydrocarbon emissions from ballasting can be eliminated entirely by the use of fully segregated ballast tanks. Evaporative venting emissions can be minimized by the employment of inert gas blanketing systems. Emissions from the storage tanks can be reduced by the use of a vapor recovery system in place of floating roofs. In general, the technology exists to minimize the impact of an oil offloading terminal and consideration should be given to the application of the best available technology for any proposed facility. However, further studies are needed to determine other available mitigating measures and to assess the effectiveness of each for minimizing the impact of a terminal.

In conclusion, oil transfer facilities of the sizes evalauted in this study have the potential for significantly impacting air quality. The actual impact would depend on the meteorological and geographical aspects of the chosen site, the actual design of the facility and the air pollution control technology employed. There appear to be several mitigating measures which have the potential to substantially reduce the air quality impact of a terminal facility. Once an oil transfer facility is proposed for a specific site, a much more extensive, detailed analysis of the impact of the project would be required to define the extent of the air impact and the specific mitigating measures that would be needed in that situation. The specifics of the project, such as berth and tank farm location, expected tanker fleet, number of storage tanks and annual port calls, as well as site-specific meteorology, terrain and existing emissions need to be evaluated before a complete assessment of the impact of that project could be made.

SUMMARY TABLE

ANNUAL EMISSIONS (TONS)

POLLUTANT	STORAGE & TRANSFER	TANKER COMBUSTION	TANKER FUGITIVE
SCENARIO I			
SO_2		1699	
NO_x		795	
PARTICULATES		194	
HYDROCARBONS	632 - 974		101 - 6630
SUB-SCENARIO IA			
SO_2		2196	
NO_x		1020	
PARTICULATES		247	
HYDROCARBONS	632 - 974		450 - 3136
SCENARIO II			
SO_2		2463	
NO_x		1146	
PARTICULATES		277	
HYDROCARBONS	861 - 1328		195 - 3537
SUB-SCENARIO IIA			
SO_2		3198	
NO_x		1500	
PARTICULATES		361	
HYDROCARBONS	861 - 1328		637 - 3939

Introduction

The Federal Energy Administration was asked by the President's Energy Resource Council to investigate the problems associated with siting a marine oil transfer terminal for Alaskan oil. One portion of this study involves an evaluation of the air quality impact of such a terminal. EPA Region X was asked by FEA to perform this evaluation of the air quality impact of a terminal upon several possible sites in the Pacific Northwest.

Scope of Study

The Region X study has three major objectives. The first is an evaluation of each site in relation to existing air quality and future air quality requirements. The second is the determination of the pollutant emissions associated with all aspects of the proposed marine oil transfer terminal. The third is an evaluation of the air quality impact of a terminal at each designated site. This evaluation involved modeling the various types of emissions associated with shipping and oil transfer and storage operations.

The Northwest Scenarios

The Northwest portion of the study involves nine sites for which there are two scenarios, each with one sub-scenario. The governing criteria for the scenarios are the daily crude oil throughput rate and current Washington State regulations concerning permissible tanker size. These criteria result in different tanker fleets and oil storage requirements. All information and unreferenced assumptions for this study including tanker fleet mixes, operating parameters and oil storage requirements were provided by the Federal Energy Administration.(1)

The nine sites are named and described below and are shown on Figures 1 through 1-9.

(1) Cherry Point (Ferndale), Washington

This is the northernmost site and is located in the Strait of Georgia, Puget Sound approximately 10 miles south of the Canadian border. The marine terminal would be located at Cherry Point with the storage tanks located between the INTALCO Aluminum Company and the ARCO refinery.

(2) March Point (Anacortes), Washington

This site is located at the north end of Fidalgo Island, east of Anacortes in Fidalgo Bay, Puget Sound. The marine terminal would be located at the northern tip of March Point with the storage tanks located near the southern end of the point.

(3) Burrows Bay, Washington

Burrows Bay is located at the west side of Fidalgo Island. The marine terminal would be located near Allan Island and the storage tanks would be at the same location as for the March Point site.

(4) Port Angeles, Washington

Port Angeles is located at the north side of the Olympic Penninsula on the Strait of Juan de Fuca. The marine terminal would be located in Port Angeles Harbor on the south side of Ediz Hook The storage tanks would be located near the conjunction of Ediz Hook and the mainland.

(5) Offshore Copalis Beach, Washington

Copalis Beach is located on the Pacific Ocean on the Olympic Penninsula and is approximately 10 miles north of the entrance to Grays Harbor. The marine terminal would be located approximately two miles offshore and the storage tanks located near Copalis Beach.

(6) Copalis Beach, Washington

This site would be the same as the Offshore Copalis Beach except that the marine terminal would be located in a dredged, inland harbor.

(7) Grays Harbor, Washington

Grays Harbor is located in the Pacific Ocean at the south end of the Olympic Penninsula. The marine terminal would be located off of Damon Point at the south end of Point Brown. The storage tanks would be located on the north side of North Bay.

(8) Offshore Clatsop County, Oregon

This site would be between Seaside and the Clatsop Spit, south of the Columbia River. The marine terminal would be approximately two miles offshore with the storage tanks located east of Warrenton.

(9) Astoria, Oregon

Astoria is approximately eight miles upstream from the mouth of the Columbia River. The site would be located approximately two miles east of Astoria at Tongue Point.

Scenario I is defined by a daily throughput rate of 1,000,000 barrels. This and a seven day storage requirement result in eleven 650,000 barrel storage tanks. A tanker fleet which would be required in order to deliver this oil is shown in Table 1. The berthing requirements would be either two berths for 165,000 dead weight ton (dwt) tankers and two for 120,000 dwt tankers or three for 165,000 dwt tankers.

Sub-scenario IA is defined by a tanker size limitation. Current Washington State law limits the size of tankers entering Puget Sound and hence the Cherry Point, March Point and Burrows Bay sites, to less than 125,000 dwt. The tanker fleet required in order to deliver oil to these sites is shown in Table 1. The berthing requirements for this sub-scenario would be either two berths for 120,000 dwt tankers and four berths for 80,000 dwt tankers or four berths for 120,000 dwt tankers. The number of oil storage tanks remains the same as that for Scenario I.

Scenario II is defined by a daily throughput rate of 1,350,000 barrels of which approximately 80,000 barrels would be foreign. This throughput rate will result in the requirement of fifteen 650,000 barrel storage tanks. The tanker fleet which would be required in order to deliver the oil is shown in Table 1. The berthing requirements would be either three berths for 165,000 dwt tankers and two berths for 120,000 dwt tankers or four berths for 165,000 dwt tankers.

Sub-scenario IIA is also defined by the Washington State tanker size laws. The tanker fleet required in order to deliver the oil to the Puget Sound sites is shown in Table 1. The berthing requirements for this sub-scenario would be either two berths for 120,000 dwt tankers, four berths for 80,000 dwt tankers and two berths for 65,000 dwt tankers or two berths for 120,000 dwt tankers and five berths for 80,000 dwt tankers. The number of oil storage tanks remains the same as that for Scenario II.

The tanker fleet of sub-scenario IIA requires practically all U. S. tankers of less than 120,000 dwt and greater than 50,000 dwt to be used to deliver the North Slope Alaskan crude. Likewise, sub-scenario IA requires a large portion of these tankers. It is unlikely, then, that either of these sub-scenarios would ever be implemented.

Site Evaluations

The ambient air quality standards applicable to the sites involved in this study are summarized in Table 2. The following is a brief description of the existing air quality situation at each site. All emission data is from the August 1976 NEDS report.

Cherry Point

There are three significant sources of emissions in the vicinity of the proposed site. These are the ARCO and Mobil Oil refineries and the INTALCO Aluminum Company. The combined annual emissions of these three facilities have been estimated to be 16,000 tons of SO_2, 2,700 tons of NO_x, 1,600 tons of particulates, 6,000 tons of hydrocarbons and 91,000 tons of CO.

The only pollutants that have been monitored extensively in the Cherry Point area are SO_2 and total suspended particulates. State and local short term SO_2 standards have been exceeded several times in late 1975 and 1976. In addition, the 1975 annual average for SO_2 was less than 1 ug/m^3 below the local annual standard.

March Point

There are six significant sources of emissions in the Anacortes-March Point area. These are the Texaco and Shell Oil refineries, the Scott Paper Company, the Allied Chemical Company, Publishers Forest Products and Northwest Petrochemical. The combined annual emissions of these facilities have been estimated to be 17,000 tons of SO_2, 2,700 tons of NO_x, 1,900 tons of particulates, 4,900 tons of hydrocarbons and 2,500 tons of CO.

Ambient SO_2 and total suspended particulates have been extensively monitored in the Anacortes vicinity. The federal, state and local short-term SO_2 standards have been exceeded several times in 1975 and 1976 but the area is in compliance with the annual standards. March Point is approximately 50 miles from the Northern Cascades National Park and emissions from a marine terminal could possibly affect air quality within the park.

Burrows Bay

There are no significant sources of emissions in the vicinity of this site. Although Burrows Bay is less than three miles from Anacortes it is separated from the city by a ridge which reaches an elevation of over 1,200 feet above sea level. There has been no ambient monitoring in this area as it is primarily either residential or undeveloped. The existing air quality is considered to be good in view of the geographical location and lack of development.

Port Angeles

There are three major sources of emissions in Port Angeles in addition to numerous wigwam burners which are principally sources of particulates. These sources are the ITT Rayonier pulp mill, the Crown Zellerbach pulp mill and the Penninsula Plywood Corporation. The combined annual emissions of these three facilities have been estimated to be 4,900 tons of SO_2, 1,000 tons of NO_2, 2,000 tons of particulates, 100 tons of hydrocarbons and 4,000 tons of CO.

Total suspended particulates and SO_2 have been monitored extensively in Port Angeles. The area presently exceeds the state and local annual standards for total suspended particulates. The short term local, state and federal SO_2 standards were also exceeded several times in 1975 and the area is classified as non-attainment for SO_2.

The proposed terminal site at Port Angeles is approximately 6 miles from the Olympic National Park and would be expected to have an impact upon air quality within the park. Port Angeles is also only 13 miles from Vancouver Island, Canada so the air quality impact in Canada must also be considered.

Copalis Beach and Offshore Copalis

There are no significant sources of emissions in the vicinity of these sites as this area is primarily resort and recreation oriented. Little if any ambient monitoring has been done in this area and the air quality is considered to be quite good.
This site is only 25 miles from the Olympic National Park and air quality within the park could be affected by emissions at the site. In addition, the site is less than 10 miles from the Quinault Indian Reservation and air quality within the reservation may be affected.

Grays Harbor

There are no significant sources of emissions in the vicinity of the Grays Harbor site as this area is also primarily resort and recreation oriented. Little if any ambient air monitoring has been done in this area and the air quality is considered to be good.

Offshore Clatsop County

There are no significant sources of emissions in the vicinity of this site as this area is primarily resort and recreation oriented. Little if any ambient monitoring has been done in this area and the air quality is considered to be good.

Astoria

There are no significant sources of emissions in the vicinity of this site. Total suspended particulate and SO_2 have been monitored for several years and the area is reported to be in compliance with national secondary and state ambient air quality standards. Table 3 summarizes the current air quality situation at each site.

Emission Calculations

Oil Storage and Transfer Emissions

For the purpose of calculating worst case hydrocarbon emissions from the storage tanks and other sources of fugitive emissions it is assumed that the true vapor pressure of the stored crude oil is equal to 9.5 pounds per square inch absolute (psia). The temperature of the oil as delivered to the Northwest sites is assumed to be 97° F. Both of these values are consistent with oil company projections for the North Slope Alaskan crude oil as delivered to the West Coast.

There is some controversy concerning the Reid vapor pressure (RVP) and hence the true vapor pressure, of North Slope Alaskan crude oil. The range of RVP's for different crudes is from greater than 14 psia for lighter crudes to less than 4.5 psia for heavy crudes.(2) North Slope Alaskan crude oil is generally considered to be a light crude and a molecular weight of 48.4(3) for its vapors substantiates this assumption. The range of RVP's for North Slope crude which have been claimed by everybody from the oil companies to the Coast Guard is from 2.9 psia to 21.2 psia. Therefore, the RVP of 8.0 used for this study appears reasonable but could be either high or low by up to a factor of two. The volume of emissions is dependent upon the RVP and increases with increasing vapor pressure. The weight of emissions is dependent upon the molecular weight and increases with molecular weight. However the relationship between RVP and molecular weight of the vapors is not clear. Thus a lower RVP would decrease the volume of emissions but if the associate molecular weight was greater this would increase the weight of emissions and somewhat offset the decrease in volume. Therefore because the value for the RVP of 8.0 (true vapor pressure of 9.5) was the only one for which an associate molecular weight was available, it has been used for this study.

Because of the rapid storage tank turnover rate of once per week and the enormous volume of each tank it was also assumed that neither the temperature nor the true vapor pressure would change appreciably during storage.

The oil storage tanks are assumed to have a 650,000 barrel effective working capacity and are 270 feet in diameter and 65 feet in height. The tanks are assumed to be new, welded, floating roof tanks with pan or pontoon roofs and modern single or double metallic or tube seals. The roof and shell would be painted white. No additional emission control techniques will be assumed.

The density of North Slope Alaskan crude oil in storage is assumed to be 312.5 pounds per barrel at 60° F. However, for the purposes of emission calculations the American Petroleum Institute recommends the use of the density of the condensed vapor for crude oil.(4) For North Slope Alaskan crude oil, Standard Oil of Ohio (SOHIO) has calculated that the density of the condensed vapors is equal to 135.6 pounds per barrel.(5)

The standing storage evaporation emissions for a storage tank can be computed using the following equation:

$$L_y = K_t \ (150)^{1.5} \ \frac{D}{(150)}\left[\frac{P}{(14.7 - P)}\right]^{0.7} V_w^{\ 0.7} \ K_s K_c K_p \qquad (6)$$

Where:

L_y = standing storage evaporative emissions, barrels per year (bbl/yr) per tank

K_t = tank factor for welded tank = 0.045

D = tank diameter, feet = 270

P = true vapor pressure of stock at its average storage temperature, psia = 9.5

V_w = average wind velocity, mph

K_s = seal factor for modern metallic or tube seals = 1.00

K_c = stock factor for crude oil = 0.75

K_p = paint factor for white = 0.90

Figure 2 provides a graph of the "standing storage evaporative emissions -vs- wind velocity" for a 270 feet diameter tank.

The withdrawal emissions for a storage tank can be calculated using the following equation:

$$W = 22{,}400 \cdot (C/D) \qquad (7)$$

Where:

W = withdrawal emissions, bbl per million bbl throughput

C = 0.02 (based on barrels of clingage per 1000 ft^2 of shell surface)

D = tank diameter, feet = 270

Using these values W = 1.66 bbl per million bbl throughput. The annual throughput for each storage tank is 33,000,000 barrels which result in annual withdrawal emissions equal to 55 barrels per year per tank. Because of the random nature of the port operations it is probable that at any given time there will be as many storage tanks being emptied as being filled. Therefore, an average hourly emission rate computed by dividing the annual loss by the number of hours per year is reasonable.

Table 4 provides the annual storage tank emissions for each site. The annual storage tank emissions are the sum of the standing storage evaporative emissions at the average annual wind speed and the withdrawal emissions.

There are several sources of fugitive hydrocarbon emissions associated with the transfer and storage operations (fugitive emissions from the tankers will be considered later). The most important of these sources are pump seals, valves and spillage. Losses from pump seals and valves have been estimated by the Los Angeles Air Pollution Control District to be 4.2 pounds per day per seal and 0.1 pounds per day per valve.(8) The U. S. Army Corps of Engineers has estimated that the spillage associated with oil offloading facilities is approximately 0.5 barrels per one million barrel throughput, a portion of which will evaporate and contribute to the fugitive hydrocarbon levels.(9) Assuming only two pump seals and six valves per storage tank and appropriate throughputs, the total losses are approximately 300 barrels per year for Scenario I and approximately 400 barrels per year for Scenario II.

The total annual hydrocarbon emissions due to storage and transfer operations for each scenario, by site, are shown in Table 5. These values are computed by summing the storage tank emissions of Table 4 for the appropriate number of storage tanks and the fugitive emissions.

Tanker Operation Emissions

The emissions from shipping operations are of two types: tanker and tugboat combustion emissions and fugitive hydrocarbon emissions from tanker operations such as ballasting, fueling, venting and purging. Combustion emissions are dependent upon engine fuel combustion rate, sulfur content of the fuel and the type of engine. Tanker engines are assumed to be steam turbines burning low viscosity fuel oil which is 1.5 percent sulfur by weight. Tugboat engines are assumed to be diesels burning diesel fuel which is 0.25 percent sulfur, by weight. The fuel consumption rates for the tankers and tugboats by operating mode are shown in Table 6.

The emission factors for tankers that are used in this study were taken from the Maritime Administration Office of Research and Development (MARAD) study.(10) The values derived in the MARAD study were the most conservative of those which were considered and therefore were adopted for this study. These emission factors, corrected for 1.5 percent sulfur, are shown in Table 7. The emission factors for tugboats were calculated from the paper "Ships as Sources of Emissions" by James R. Pearson.(11) These emission factors, based on 0.25 percent sulfur in fuel, are also shown in Table 7. Tables 8A through 8G show the hourly emission rates by operating mode for the tankers and tugboats.

There are two distinct types of tankers which are being utilized in this study. The first are tankers which are equipped with inerting systems and fully segregated ballast. The second are tankers without inerting systems and which have only approximately 15 percent segregated ballast. The inerting tankers will arrive in port, offload their cargo while inerting the atmosphere in the cargo tank and at the same time be taking on ballast. Sometime after offloading is completed the cargo tanks may be purged with inert gas. The non-inerting tankers will arrive at port, offload their cargo and at the same time take on what ballast they can into their segregated tanks. After offloading is completed, further ballast may or may not be loaded into the cargo tanks.

There are four major sources of fugitive hydrocarbon emissions associated with tanker operations. These are (1) emissions resulting from the filling of non-segregated ballast tanks, (2) emissions resulting from fueling operations, (3) the natural venting which occurs on non-inerting tankers after offloading is completed and (4) the purging operations of inerting tankers.

In order to compute the hydrocarbon emissions associated with the ballasting operation, one can simulate the situation of an empty tanker being filled with water as that of a fixed-roof storage tank being filled with crude oil. In both cases, hydrocarbon vapors are displaced by the incoming liquid and forced out of the tank through either pressure relief valves or open vents. The equation for computing the emissions would then be:

$$F_{co} = \frac{2.25\ PV}{(10,000)} \cdot K_t \qquad (12)$$

Where:

F_{co} = emissions, bbl

P = true vapor pressure, psia = 9.5

V = volume pumped into tank, bbl

K_t = turnover factor = 0.23

The turnover factor K_t is determined by the following rationale. Because the tanker is emptied and ballasted in approximately one day, a one day turnover rate (365 turnover per year) can be assumed. Therefore from Figure 486(13), $K_t = 0.23$.

It is common practice to ballast tankers to approximately 35 percent of their dead weight tonnage. This is usually done in two stages with 10 percent to 15 percent ballasted in berth and the remainder when the tanker is underway. However, in times of severe winds or high seas, all ballasting may be completed in berth. For purposes of this study it has been assumed that tankers with non-segregated ballast will also have some segregated ballast to the order of 15 percent of their dead weight tonnage. In this case the fugitive emissions will be associated with the ballasting of 20 percent of the dead weight tonnage which occurs only in times of severe winds or high seas. It is also assumed that the ballasting rate is 5 percent of the dead weight tonnage per hour. Table 9 shows the emissions associated with ballasting for tankers with non-segregated ballast.

Fugitive emissions from fueling operations will occur at all sites except the Offshore Copalis and Clatsop sites. The Reid vapor pressure of residual oil is approximately 0.0004 psia.(14) The maximum fuel requirement for a round trip to Valdez from any of the Northwest sites would be approximately 1600 tons.(15) Even when assuming that loading 1600 tons of fuel displaces an equal volume of gas containing hydrocarbons at equilibruim concentration the resulting emissions would be less than 1 pound of hydrocarbons for the entire fueling operation. These emissions are so small as to be negligable and will not be considered in the remainder of this study.

In order to calculate the fugitive emissions during the venting and purging operations, the hydrocarbon concentration in the empty tank immediately after offloading must first be computed. This can be done by calculating the average concentration of the ballasting emissions and assuming that this concentration is uniform throughout the tank. This is a reasonable technique because the gas mixing rate is high during offloading. Using the emissions per volume of gas displaced determined for ballasting, the ideal gas law and a molecular weight for Alaskan crude vapors of 48.4, the concentration is found to be approximately 12 percent.

Recent studies of hydrocarbon concentrations in empty tanker holds show that the vapors are usually stratified. There is a dense layer of vapors, usually less than 2 meters in depth, at the bottom of the tank where the concentration approaches equilibrium. Above this layer the concentration is lower and generally uniform throughout the tank. A British Petroleum Company study(16) measured a range of average concentrations for vapors above the dense layer of 1 percent to 9 percent for crudes with lower TVP than North Slope crude. Therefore, a concentration of 12 percent is not unreasonable but should most likely be considered as a worst case with regard to emissions.

In order to calculate the venting emissions for tankers without inerting systems it is also necessary to calculate an evaporation rate for crude oil from the sides and bottom of the emptied tanker. This can be done using the following procedure:

Assumptions:

1) 80,000 dwt tanker
2) V = volume of tanker = 560,000 barrels
3) U = volume of ullage space = 18,000 barrels (ullage space is defined as the difference in volume of tanker and volume of oil in tanker)

4) Temperature in the tanker is assumed to be equal to the delivery temperature of 97°F.

5) C_i = initial hydrocarbon vapor concentration in ullage space = 60 percent (slightly below equilibrium concentration)

6) C_f = final hydrocarbon vapor concentration in emptied tanker = 12 percent

7) E_r = average evaporative rate in barrels per hour, which is assumed to be constant over time and equal for the walls and oil surface.

8) Time required to offload the oil, or to increase the initial volume U to the final volume V, is 24 hours.

The final volume of hydrocarbon vapors in the emptied tanker, W_f, can be calculated by using the formula

$$W_f = VC_f$$

The initial volume of hydrocarbons in the ullage space, W_i, can be calculated by using the formula

$$W_i = UC_i$$

A simple equation can then be written which will allow the calculation of the hourly evaporative rate E_r

$$W_f = W_i + 24\ E_r$$

That is, the final volume, in barrels, is equal to the initial volume, in barrels, plus the evaporative rate, in barrels per hour, times 24 hours, the time required for offloading.

Solving this equation for the evaporate rate E_r it is found that

$$E_r = \frac{W_f - W_i}{24} = 2350 \text{ bbl/hr}$$

This then is the volume of gas that will be expelled from the empty tanker per hour due to continuing evaporation within the tanker. The concentration of the gas being expelled will be approximately 12 percent immediately after offloading and will increase with time. After eight hours the concentration in the tanker will be approximately 15 percent. Using the ideal gas law, the average hourly emission rate can be computed for this eight hour period. For this case it would be 240 pounds per hour. Noting the fact that, in this case, the evaporation rate is approximately 0.4 percent of the tanker volume per hour and assuming that the other tankers should behave similarly, the evaporation rate and average hourly emission rate for the first eight hours can be computed for each tanker. Those values are given in Table 10.

Purging emissions are associated with tankers equipped with inerting systems. The purging operation efficiently flushes the empty oil tank with scrubbed combustion gas in a short time. For large oil tankers a complete atmosphere change for each cell can be accomplished in approximately 80 minutes.(17) For the purposes of this study it will be assumed that the purging rate is equal to the maximum inerting rate of 10,000 cubic feet per minute (cfm). A normal purging operation encompasses three complete atmospheric changes and hence for the tankers in this study will require between 24 and 32 hours depending on the size of the tanker.

The hydrocarbon emissions associated with purging can be calculated by simulating the situation as a simple dilution. Scrubbed flue gas from the inerting system is pumped in at a rate of 10,000 cfm which displaces an equal volume of gas containing hydrocarbons at a constantly decreasing concentration. Calculating the concentration in the tanker at different times during the purge and hence the total emissions up to that time it becomes apparent that the concentration follows an e^{-at} relationship. It was found that the emissions could be calculated by using the equation

$$E_t = 0.12269VC_o(1 - e^{-(R/V)t})$$

Where

E_t = emissions from the beginning of purge to time t, lbs

V = volume of cell or cells being purged, ft^3

C_o = initial hydrocarbon concentrations in cell, percent

R = inert gas input rate, ft^3/hr

t = time, hours

0.12269 = constant from ideal gas law converting volume of emissions to pounds of emissions

which fits the theoretical situation and the calculated values extremely well.

A problem arose in determining whether the available inert gas was diverted to an individual cell in the tanker or dispersed evenly throughout all cells in the tanker. As this problem has not been resolved the purging emissions have been calculated for both situations. Table 11A contains the emissions for simultaneous purging of all cells and Table 11B contains the emissions for sequential purging of cells in which the volume of the largest cell is considered to be approximately 15 percent of the volume of the tanker. In both cases the initial concentration C_o was assumed to be 12 percent and the inert gas input rate R to be 600,000 cubic feet per hour.

The situations in which purging will actually occur are thought to be few. Purging must be done prior to drydocking or manual inspection. However, it has not been ascertained as to whether purging will be done routinely to minimize the possibility of explosion and fire hazard. At present it must be assumed that purging would be an infrequent operation.

Scenario Emissions

In order to model the air quality impact of the tanker operations it must first be determined what the most probable average and worst case tanker conditions are to be. Therefore, the procedures of tankers in the vicinity of port must be defined and the emissions associated with these procedures must be determined. Tables 12A and 12B outline the operating procedures of tankers with and without inerting systems and segregated ballast and detail the type of sources of emissions for each procedure.

During the maneuvering modes at inland water ports and during offloading at offshore ports there will be tugboat activities associated with tanker operations. The offshore ports will use one tug per tanker and inland water ports will use several tugs per tanker as follows:

tankers less than 80,000 dwt - 2 tugs

120,000, 130,000 and 150,000 dwt tankers -3 tugs

165,000 dwt tankers -4 tugs

Using Table 12A and 12B the total emissions per port call can be computed for each tanker. These emissions are given in Table 13. Using Table 13 and the appropriate tanker fleet, the total annual emissions can be computed for each scenario and sub-scenario. These values are given in Table 14. Since the tankers will arrive in port in a random pattern with respect to time it is reasonable to obtain an average hourly emission rate for tanker operation at a port by dividing the total annual emissions by 8760, the number of hours per year. These average hourly emission rates are given in Table 15 for each scenario and sub-scenario.

Associated with each scenario and sub-scenario is an average weekly tanker arrival rate. These are for Scenario I-7 tanker arrivals per week, for Sub-scenario IA-13 tanker arrivals per week, for Scenario II-10 tanker arrivals per week for Sub-scenario IIA-20 tanker arrivals per week. The situation in which all the tankers scheduled to arrive in a given week are in port at the same time can be expected to occur at least once or twice a year. This would result in all berths being occupied and the remainder of the tankers waiting at idle in the vicinity of the port. However the tankers waiting at idle would have little impact upon the port due to the low emission rates and distance from the anchorage to the port. Thus the situation in which all berths are occupied will be considered to be the "worst case" tanker situation. This will occur somewhat more frequently than the situation mentioned above and is expected to occur approximately once every week in two weeks. This "worst case" tanker situation would result in worst case emissions for periods up to 24 hours.

In the modeling of the impact of tanker operations the average hourly emissions of Table 15 will be used for the normal or representative case emissions for both short and long term standards. The emissions associated with the "worst case" tanker situation, shown in Tables 16 and 17, will be used as worst case emissions for short term standards up to 24 hours. As there are no worst case emissions which could be associated with a long term standard the representative case emissions must suffice.

In order to determine the frequency of occurrence of the various tanker emission situations a computer model was developed. This model simulates tanker activities between the loading port at Valdez, Alaska and a receiving port in the Pacific Northwest for a period of 10 years. The model provides the frequency of occurrence of berth occupation and the frequency of occurrence of emission values for each time period of interest. The frequency of occurrence for Scenarios I and II of 1-hour, 3-hour and 24-hour SO_2 emissions are shown in Tables 18A through 18F. A more detailed description of the tanker simulation model is contained in Appendix I.

Comparison of Emissions

It is useful at this point to compare the total annual emissions of the marine terminal with the total annual emissions from the significant sources in the vicinity of the port site.

Cherry Point

For the Cherry Point site the increase in SO_2 emissions would be between 11 percent and 20 percent of the current emissions depending on which scenario or sub-scenario is implemented. The increase in NO_x emissions would be between 29 percent and 56 percent, particulates, 12 percent to 23 percent and CO would increase imperceptibly. Hydrocarbon emissions would increase by between 13 percent and 158 percent depending upon whether or not the tankers purged or ballasted near the port.

March Point

For the March Point site the increase in SO_2 emissions would be between 10 percent and 19 percent, NO_x, 29 percent to 56 percent, particulates, 10 percent to 19 percent and CO, 1 percent to 2 percent. The increse in hydrocarbons would be between 17 percent and 195 percent depending on whether or not the tankers purged or ballasted near the port.

Port Angeles

For the Port Angeles site the increase in SO_2 emissions would be between 35 percent and 50 percent, NO_x, 80 percent to 115 percent, particulates, 10 percent to 14 percent and CO less than 1 percent. The increase in hydrocarbons would be between 856 percent and 9565 percent depending on whether or not the tankers purged or ballasted near the port. (The large percentage increases for hydrocarbons result from the low level of present hydrocarbon emissions in the Port Angeles area.)

It appears then, that for all pollutants except CO and possibly particulates, there would be a substantial increase in emissions above the existing at the vicinity of these three sites.

Air Quality Modeling

Modeling Approach

In order to assess the impact of the emissions from the tankers and storage tanks, a screening level modeling analysis was performed. The impact of tanker stack emissions were evaluated using gaussian plume dispersion models for point sources. The impact of tank farm and fugitive hydrocarbon emissions were evaluated by use of the Gifford* turbulent wake flow method for volume sources.

In order to obtain a preliminary indication of the meteorological conditions which could lead to high concentrations as a result of tanker stack emissions, the EPA computer model PTMAX was run. This model utilizes stack parameters and an array of stability classes and wind speeds to predict the final plume height, the maximum concentration and the distance to the maximum for each stability/wind speed combination. The input stack parameters and the results of this model for a normalized emission rate of 1 gram/second (gm/sec) are included in Appendix II.

In addition, the EPA computer model PTDIS was run for several of the stability/wind speed cases which showed the greatest impact over the 2 to

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* Gifford, F. A., 1975: Atmospheric Dispersion Models for Environmental Pollution Applications, in Lectures on Air Pollution and Environmental Impact Analysis, American Meteorological Society, 29 September - 3 October 1975, Boston, MA, pp. 49-50.

5 km range. This was done in order to better understand the relationships of plume heights and concentrations with downwind distance. Results of these runs are also included in Appendix II.

A quick comparison of the final plume heights and the terrain in the immediate vicinity of the sites shows that in many cases the receptor elevation is equal to or greater than that of the plume. This indicates that a terrain interactive model would be necessary in order to assess the impact of the tanker emissions. Therefore, the EPA valley model was utilized for stable conditions and low wind speeds in order to estimate the impact of plume impingement upon hillsides near several of the sites. The input parameters and results of this modeling are summarized in Appendix II.

The emissions from the tank farm and the fugitive hydrocarbon emissions from the tankers were treated as volume sources and evaluated using the Gifford turbulent wake flow method. Because this method is dependent upon the cross-sectional area and in order to account for various tank farm or tanker configurations, three basic formations were evaluated: in-line across wind, in-line along wind and clustered formation. The input parameters and results of this modeling are also included in Appendix II.

Air Quality Impact Predictions

Before discussing the impact of an oil transfer facility upon air quality at the various sites, it must first be pointed out that this modeling approach is diagnostic in nature and serves only to indicate for which pollutants and sites, potential air quality problems may exist. Because no attempt has been made to evaluate the meteorology of each site, the actual concentrations which might be expected to occur, the locations, or the frequency of occurrence cannot be predicted. Therefore, this modeling evaluates the short term impact of a terminal under meteorological conditions which might reasonably be expected to occur in the area. Only the distances and elevations of receptors used in the terrain interaction modeling are site specific. In addition, no attempt has been made to evaluate the impact at the offshore sites because of uncertainties in tanker spacing and location.

The discussion of the air quality impact will be limited to certain meteorological conditions and distances. Because of the sea/land interface and the influence of a large water body upon local meteorological patterns, extremely stable and extremely unstable conditions will occur infrequently. Therefore, only the impacts under stabilities B, C, D and E have been evaluated. In addition, the average distances from the tanker berths to land (with the exception of the offshore sites) and from the storage tanks to the property line are about 0.5 kilometers (km). Therefore, no discussion of the impacts of less than 0.5 km has been included.

The flat terrain modeling approach for tanker stack emissions indicates that the greatest impact would occur under stability B with 5 m/sec winds at a distance of 0.7 km. The predicted concentrations of the various pollutants for short term worst case emissions are shown in Table 19. With the exception of SO_2, all other pollutant concentrations resulting from tanker stack emissions are well below applicable standards. However, SO_2 concentrations are approximately one half of the state and local primary hourly standard and 80 percent of the state and local secondary hourly standard. It should be noted that these concentrations are the result of a simplification that all emissions are from a single point source. In reality, the tanker berth spacing is such that at so close a distance as 0.7 km, concentrations would normally be lower than those shown in Table

19. Table 20 shows the predicted concentrations at a distance of 2.3 km for stability D and 7 m/sec winds. In this case the predicted SO_2 concentrations are approximately one third of the primary hourly and one half of the secondary hourly standard.

The results of the terrain interaction modeling, however, indicate that the potential exists for higher concentrations due to plume impingement upon the steep terrain in the vicinity of some sites. As a result, concentrations of NO_x and TSP, in addition to SO_2, would become substantial. Table 21 shows the maximum predicted concentrations for the four sites evaluated by the terrain interaction modeling. This modeling shows that the state and local primary hourly standard for SO_2 could be violated at the Burrows Bay and March Point sites as a result of tanker emissions alone. In addition, the state and local secondary hourly standard for SO_2 could be violated at the Port Angeles and Cherry Point sites. However, there currently exists substantial SO_2 emissions near the Port Angeles, March Point and Cherry Point sites as well as known ambient SO_2 violations. A contribution by new tankers of the magnitude found by this modeling would compound the existing problem and likely increase the probability of violations of SO_2 standards at these three sites. Also, an additional source of particulates in Port Angeles could compound the existing TSP problem and hinder attainment of the annual state and local standard.

In summary, this modeling indicates that tanker stack emissions have the potential to produce significant short term SO_2 concentrations. A more detailed modeling analysis which looks at such situations as the offshore fumigation and limited mixing cases in addition to plume inpingement, and which utilizes site specific meteorology to evaluate frequency of occurrence and 24 hour and annual averaging times, will be necessary in order to accurately assess the impact of tanker stack emissions at a terminal site. In addition, at those sites which have existing sources of SO_2, a multiple source modeling study will be required in order to evaluate the incremental impact of the tankers upon existing air quality. In addition, it should be noted that the SO_2 concentrations could be as much as twice as great as those predicted herein if a residual fuel oil with the more common sulfur content of 2.5 to 3.0 percent is used.

The volume source modeling for fugitive hydrocarbon emissions from the tankers indicates that the greatest impact would occur under Stability E with 2.5 m/sec winds. Table 22 shows the predicted maximum concentrations for short term worst case emissions. The modeling shows that for stable conditions, purging would result in concentrations many times in excess of the National Ambient Air Quality Standards (NAAQS) under any tanker configuration. Even without purging, venting emissions alone could result in concentrations in excess of the NAAQS for relatively short distances from the berths.

Table 23 shows the predicted concentrations for good dispersion conditions of Stability D and 10 m/sec winds. These results show that even in a good dispersion situation, purging could cause hydrocarbon concentrations much greater than the NAAQS. Venting could also have a significant impact for short distances from the berths.

Although it has been assumed that ballasting would generally occur only during high winds and rough seas which indicates good dispersion conditions, the high emission rate associated with ballasting could still produce significant HC concentrations. Table 24 shows the predicted hourly concentrations as a result of ballasting emissions for Stability D and 20 m/sec winds. The results show that ballasting could result in concentrations in excess of the NAAQS within short distances of the berths.

In summary, the modeling indicates that purging emissions have the potential to create hydrocarbon concentrations which would exceed the NAAQS under any meteorology. Therefore, since purging is an optional procedure which may be regulated, it should be prevented from occurring wherever it could adversely affect air quality over land. Ballasting emissions also have the potential to cause hydrocarbon concentrations in excess of the NAAQS and hence should be prevented from occurring as much as possible. The use of fully segregated ballast tanks can reduce ballasting emissions to zero. Since venting emissions may also result in high concentrations near the berths, adequate control technology should be developed in order to reduce these emissions. Finally, all of the modeling predictions herein are directly proportional to the hydrocarbon concentration in the tanker holds which in turn is directly proportional to the true vapor pressure of the crude oil. Therefore, should any further information regarding the concentrations in empty tanker holds or regarding the vapor pressure of North Slope crude become available, all values can be simply linearly scaled to give new predictions.

The predicted concentrations for the volume modeling of a tank farm in clustered formation are shown in Table 25. This modeling shows that under most meteorological conditions the tank farm emissions could result in hydrocarbon concentrations above the NAAQS within a kilometer of the tank farm. For Stabilities D and E, significant concentrations could result for distances of several kilometers. It is apparent that further consideration need given to the use of vapor recovery systems rather than floating roofs as the emission control device for storage facilities of this magnitude. A more detailed, site specific analysis would also need to account for the combined impact of tank farm and fugitive tanker emissions.

The significant HC and NO_x emissions from a transfer terminal and the predicted concentrations discussed above lead to the question of photochemical oxidants. The hydrocarbon/oxidant relationship for the Pacific Northwest environment is not yet well understood. However, the massive HC emissions associated with purging and ballasting could create the potential for a photochemical oxidant problem. Further study is required to determine the hydrocarbon/oxidant relationship and to predict the photochemical oxidant concentrations which could result from the operation of an oil transfer facility and tank farm.

Conclusions

1) The air at the Burrows Bay, Copalis Beach, Grays Harbor, Offshore Clatsop County and Astoria sites is still relatively clean. However, existing pollutant concentrations in the vicinity of the Cherry Point, March Point and Port Angeles sites are close to exceeding or actually exceeding applicable ambient standards with regards to SO_2 and in the case of Port Angeles with both SO_2 and TSP.

2) SO_2 emissions from tankers are substantial due to the high fuel consumption rates required for offloading and would result in a significant increase in SO_2 emissions above that already existing at all of the sites.

3) The fugitive hydrocarbon emissions associated with tanker operations such as purging and ballasting are substantial and would greatly increase the existing hydrocarbon emissions in the vicinity of a site.

4) The hydrocarbon emissions from a tank farm could be substantial and would add a continual source of emissions to the vicinity of a site.

5) Due to uncertainties in the Reid vapor pressure of North Slope Alaskan crude and in the hydrocarbon concentrations in empty tanker cells, the hydrocarbon emissions calculated herein are only first order approximations. However, any reasonable corrections would likely not change the nature of the conclusions regarding hydrocarbons.

6) The SO_2 emissions from tankers have the potential to create air quality problems, especially for sites with elevated terrain and/or existing SO_2 emission sources. In addition, the use of a residual fuel oil with a higher sulfur content than the 1.5 percent assumed in this study could greatly increase the potential for adverse impact.

7) The fugitive hydrocarbon emissions from purging or ballasting operations if done near port without mitigating measures would cause massive violations of the NAAQS for hydrocarbons and could likely create a photochemical oxidant problem.

8) The hydrocarbon emissions from the tank farm and tanker activities other than purging and ballasting could cause violations of the NAAQS for hydrocarbons and could contribute to a photochemical oxidant problem.

9) The direct impact of an oil transfer facility upon NO_x and CO air quality should be minimal. However, NO_x could be a factor in increased potential for oxidant formation.

(10) The particulate emissions from tugs and tankers could compound the TSP problems at sites such as Port Angeles at which applicable air quality standards are currently exceeded.

(11) In general, an oil transfer facility of the size evaluated in this study would have a significant adverse impact upon air quality and a strong potential for causing and/or contributing to violations of ambient air quality standards.

(12) Purging emissions and ballasting emissions, both of which can be prevented from occurring with available technology, should be prevented from occurring wherever air quality over land could be adversely affected.

(13) Methods of reducing SO_2 emissions from tankers during off-loading such as the use of low sulfur fuel or the application of emission control equipment should be investigated.

(14) Further studies need to be done with regards to quantifying fugitive hydrocarbon emissions from tanker operations and to adequately describe the hydrocarbon/photochemical oxidant relationship for the Pacific Northwest.

(15) Further studies are needed to determine the extent of mitigating measures which are currently available and to evaluate the effectiveness of each for reducing the air quality impact of a terminal. In addition, the economics of and timetable for implementing any mitigating measures must be addressed. The cost and feasibility of retrofitting existing tankers with segregated ballast, inerting systems or other necessary emission control equipment and the economics of only permitting tankers equipped with certain emission control technologies to use the port must be evaluated with regard to the reduction of air quality impact which could be achieved.

(16) A much more extensive, detailed analysis of the air quality impact of a transfer facility upon the vicinity of a site will need to be done if and when a specific project is proposed.

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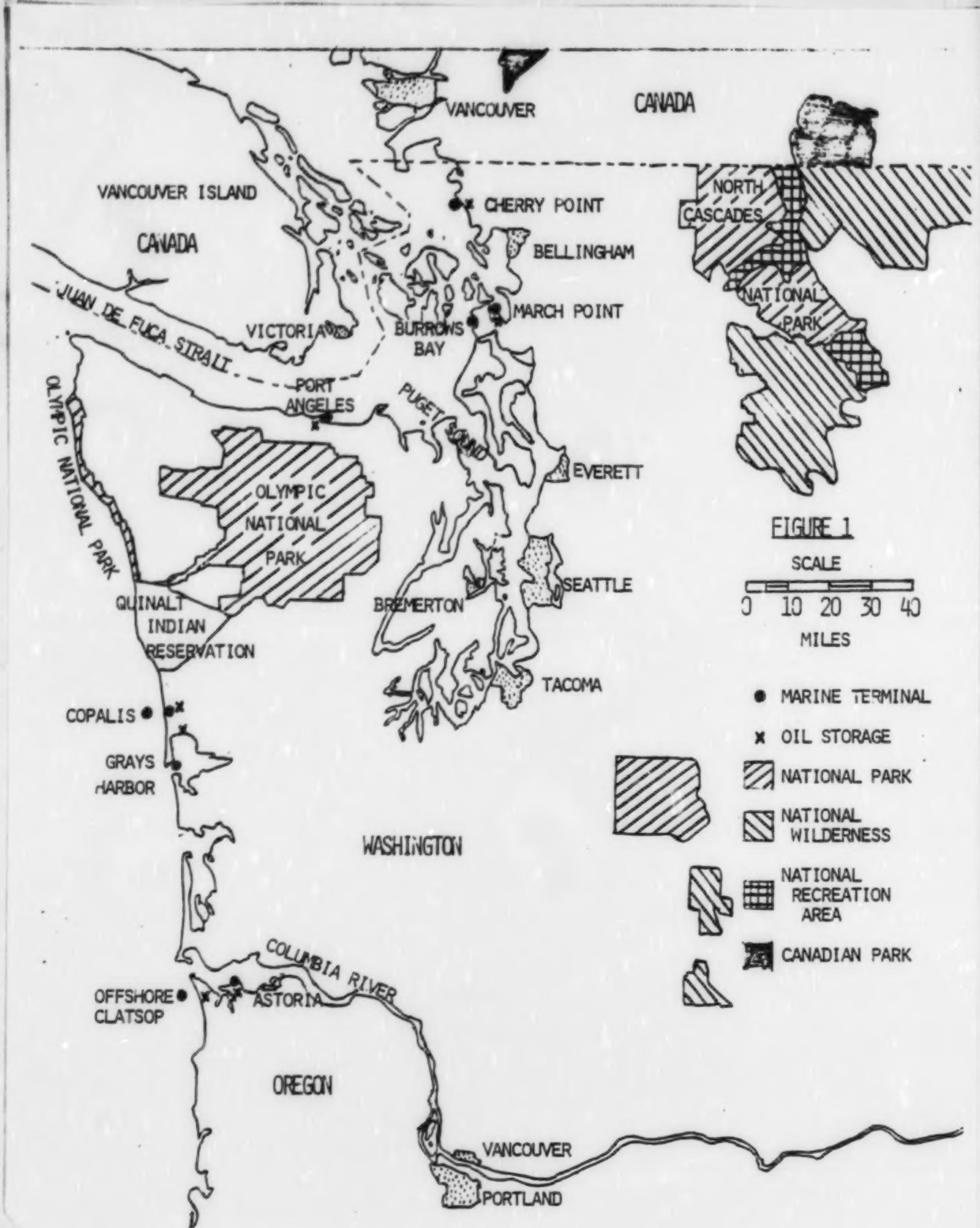
VANCOUVER
CANADA
VANCOUVER ISLAND
CHERRY POINT
CANADA
BELLINGHAM
NORTH CASCADES NATIONAL PARK
JUAN DE FUCA STRAIT
VICTORIA
BURROWS BAY
MARCH POINT
PORT ANGELES
PUGET SOUND
OLYMPIC NATIONAL PARK
OLYMPIC NATIONAL PARK
EVERETT
SEATTLE
BREMERTON
QUINALT INDIAN RESERVATION
TACOMA
COPALIS
GRAYS HARBOR
WASHINGTON
COLUMBIA RIVER
OFFSHORE CLATSOP
ASTORIA
OREGON
VANCOUVER
PORTLAND
SCALE
0 10 20 30 40
MILES
● MARINE TERMINAL
x OIL STORAGE
NATIONAL PARK
NATIONAL WILDERNESS
NATIONAL RECREATION AREA
CANADIAN PARK

FIGURE 1

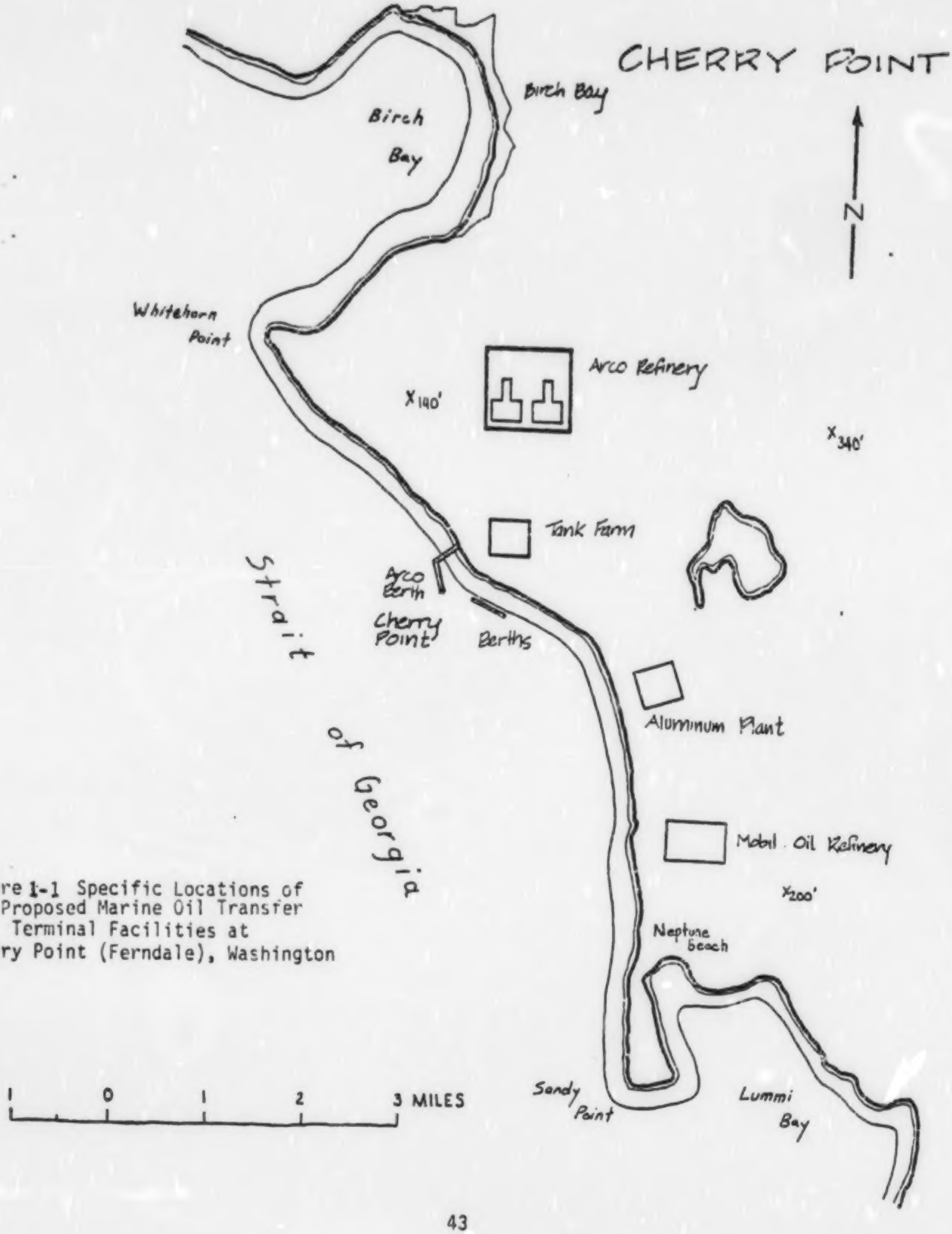
CHERRY POINT
N
Birch Bay
Birch Bay
Whitehorn Point
Arco Refinery
X140'
X340'
Tank Farm
Arco Berth
Cherry Point
Berths
Strait of Georgia
Aluminum Plant
Mobil Oil Refinery
X200'
Neptune beach
Sandy Point
Lummi Bay
1 0 1 2 3 MILES

Figure 1-1 Specific Locations of the Proposed Marine Oil Transfer Terminal Facilities at Cherry Point (Ferndale), Washington

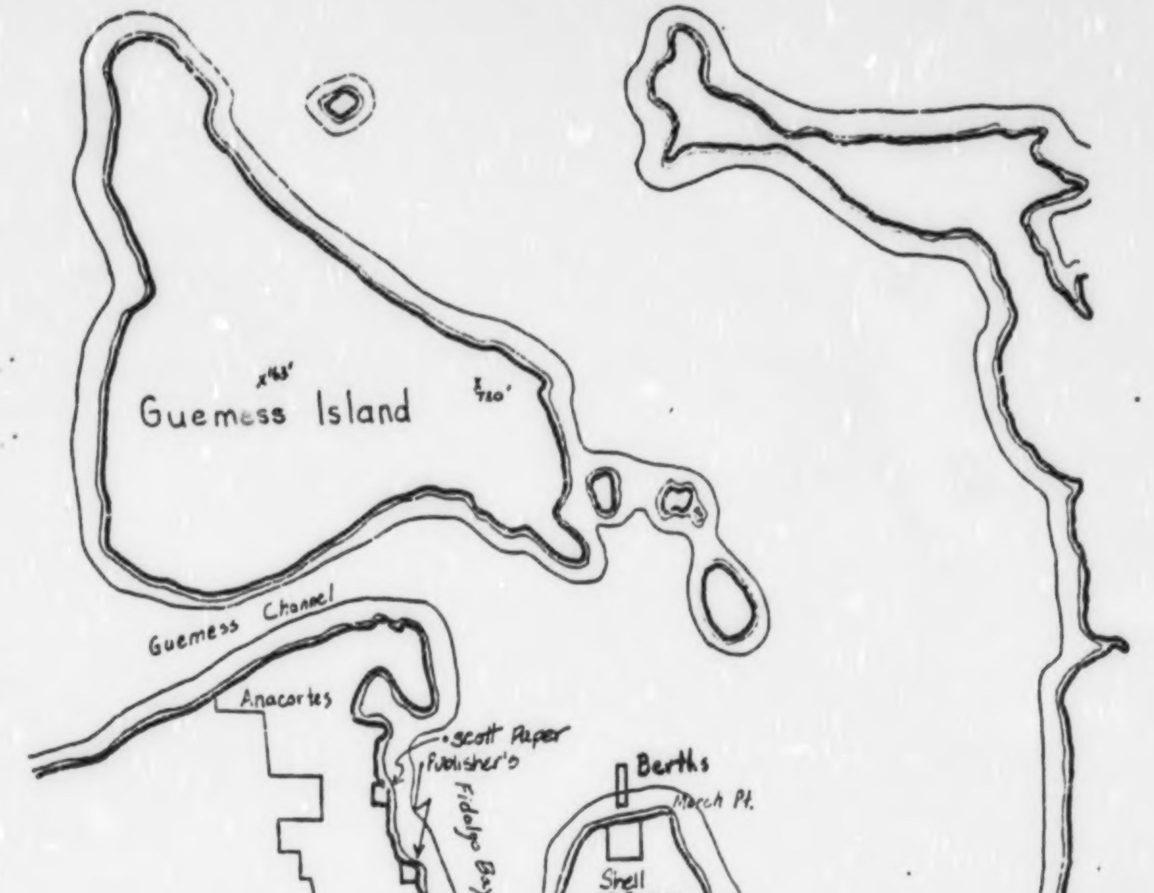
x463'
Guemess Island
x710'
N
Guemess Channel
Anacortes
• Scott Paper
Publisher's
Fidalgo Bay
Berths
March Pt.
Shell Refinery
Allied Chemical
Northwest Petrochemical
Padilla Bay
Texaco
Tank Farm
x850'
Lake Campbell
Similk Bay
MARCH POINT
1 0 1 2 3 4 MILES

Figure 1-2 Specific Locations of the Proposed Marine Oil Transfer Terminal Facilities at March Point, Washington

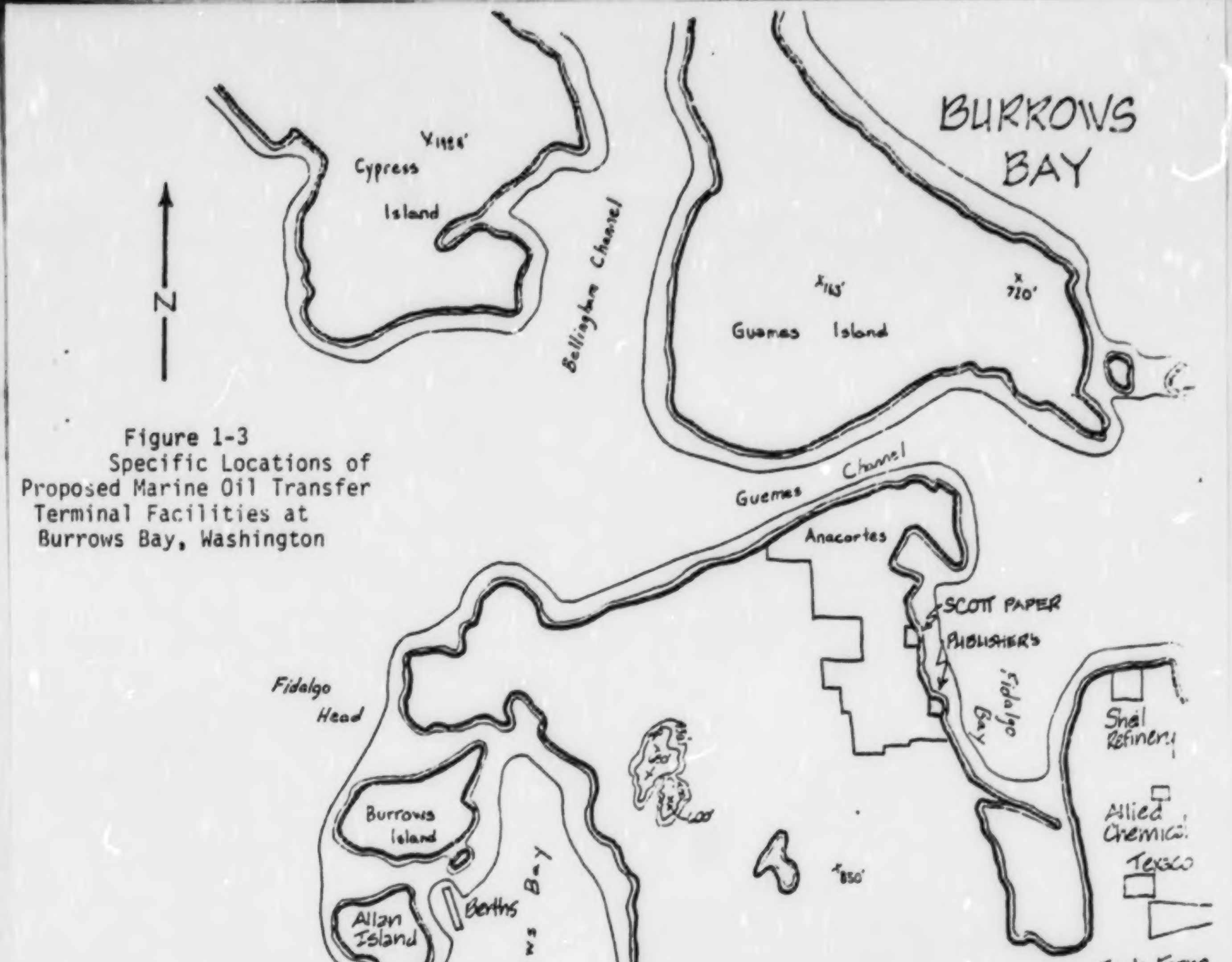
BURROWS BAY
N
Cypress Island
x1525'
Bellingham Channel
Guemes Island
x165'
x720'
Guemes Channel
Anacortes
SCOTT PAPER
PUBLISHER'S
Fidalgo Bay
Shell Refinery
Allied Chemical
Texaco
Tank Farm
Fidalgo Head
Burrows Island
Allan Island
Berths
Burrows Bay
x850'
Rosario Strait
Lake Campbell
Similk Bay
Deception Pass
1 0 1 2 MILES

Figure 1-3
Specific Locations of Proposed Marine Oil Transfer Terminal Facilities at Burrows Bay, Washington

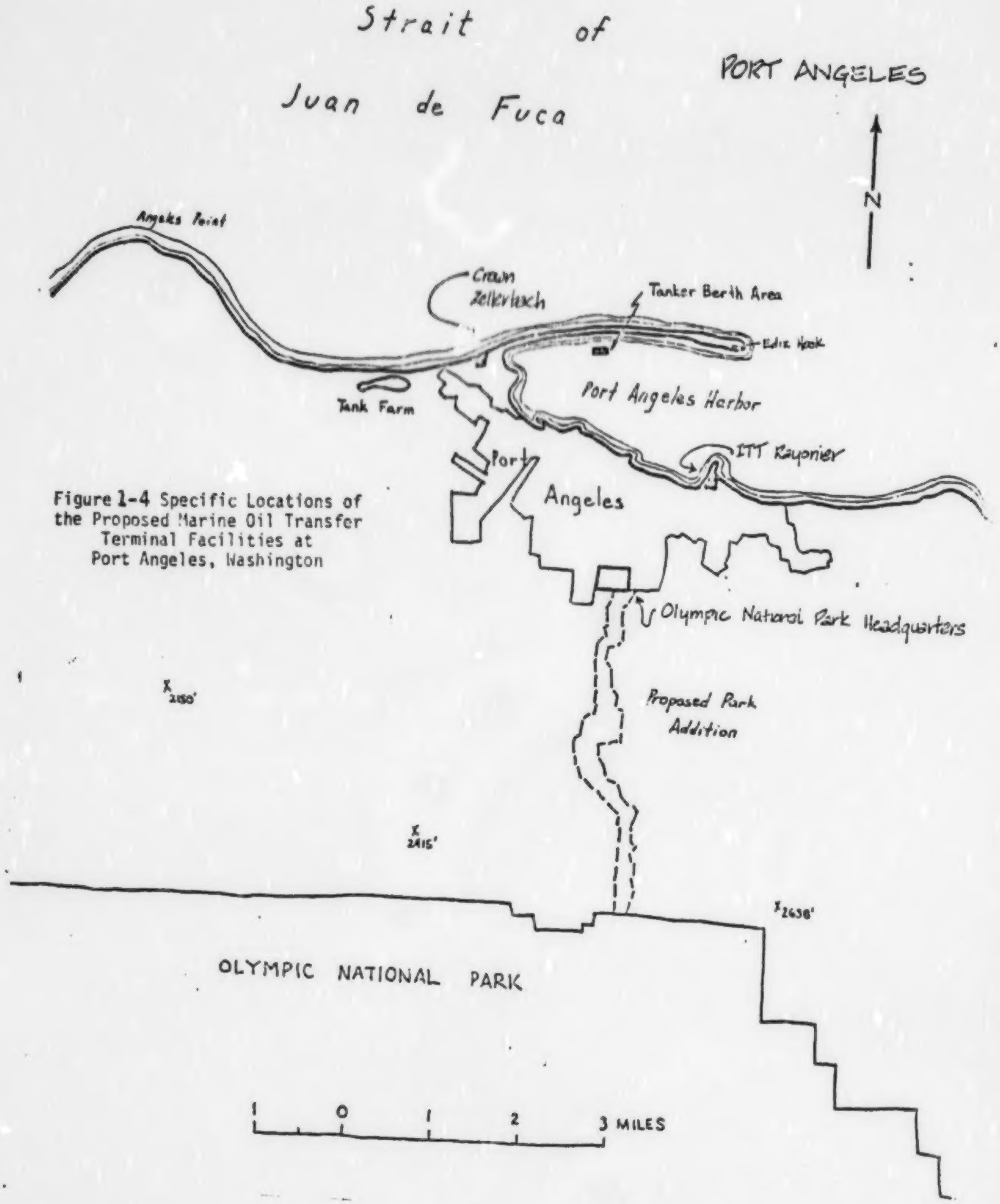
Strait of Juan de Fuca
PORT ANGELES
N
Angeles Point
Crown Zellerbach
Tanker Berth Area
Ediz Hook
Port Angeles Harbor
Tank Farm
ITT Rayonier
Port Angeles
Olympic National Park Headquarters
Proposed Park Addition
2150'
2415'
2638'
OLYMPIC NATIONAL PARK
1 0 1 2 3 MILES

Figure 1-4 Specific Locations of the Proposed Marine Oil Transfer Terminal Facilities at Port Angeles, Washington

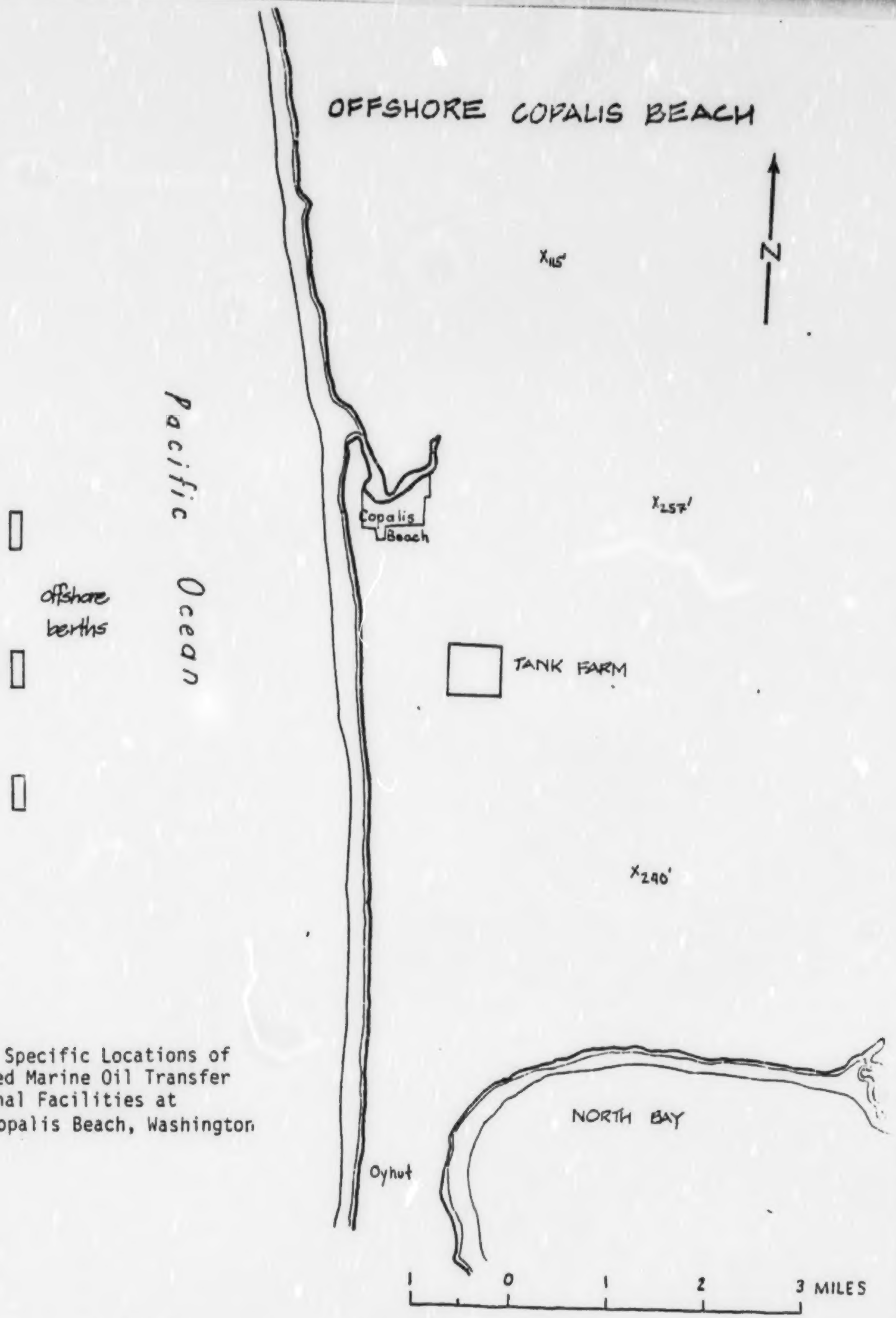
OFFSHORE COPALIS BEACH
N
X115'
Pacific Ocean
Copalis Beach
X257'
offshore berths
TANK FARM
X240'
NORTH BAY
Oyhut
1 0 1 2 3 MILES

Figure 1-5 Specific Locations of the Proposed Marine Oil Transfer Terminal Facilities at Offshore Copalis Beach, Washington

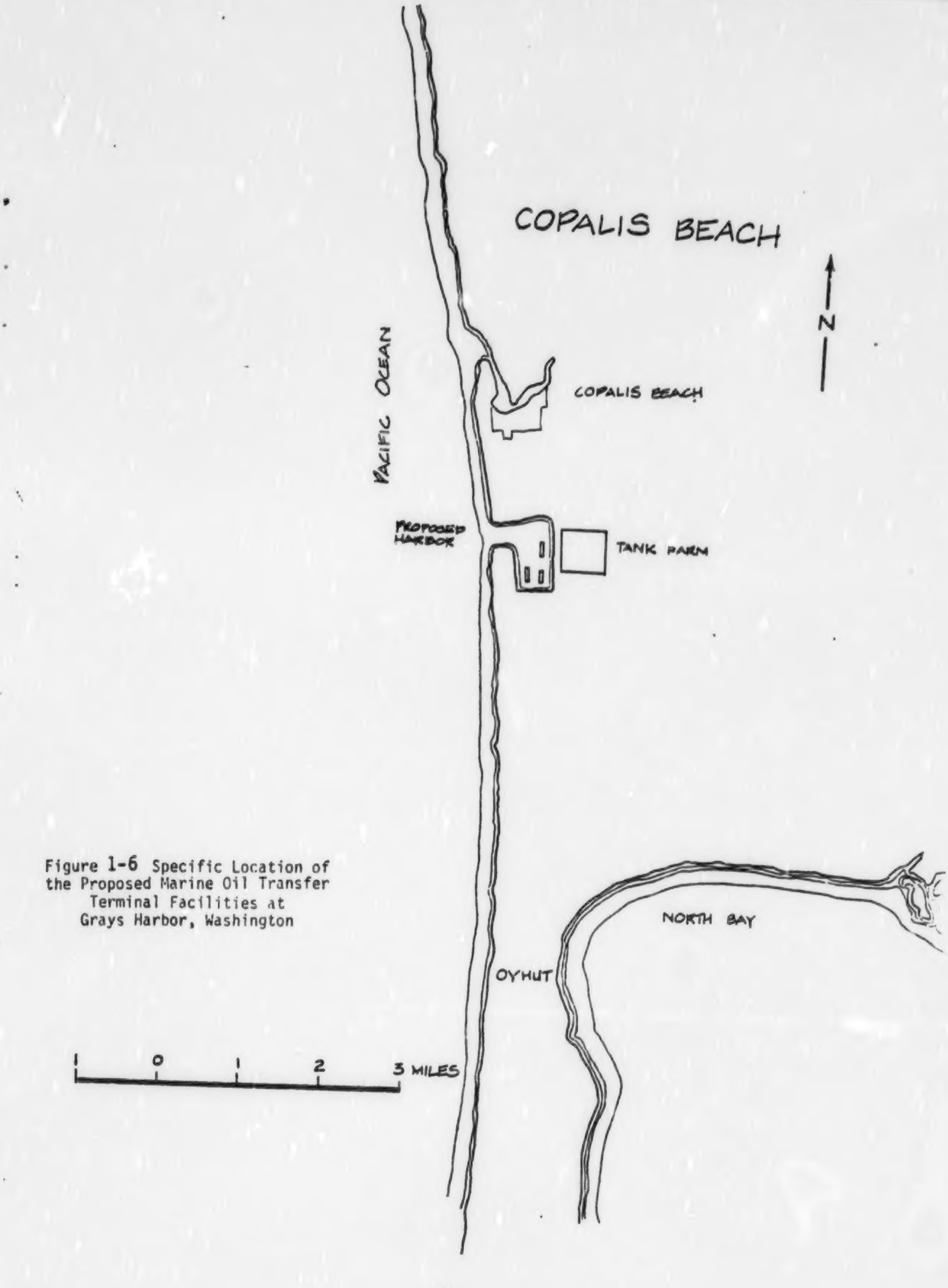
COPALIS BEACH
N
PACIFIC OCEAN
COPALIS BEACH
PROPOSED HARBOR
TANK FARM
NORTH BAY
OYHUT
1 0 1 2 3 MILES

Figure 1-6 Specific Location of the Proposed Marine Oil Transfer Terminal Facilities at Grays Harbor, Washington

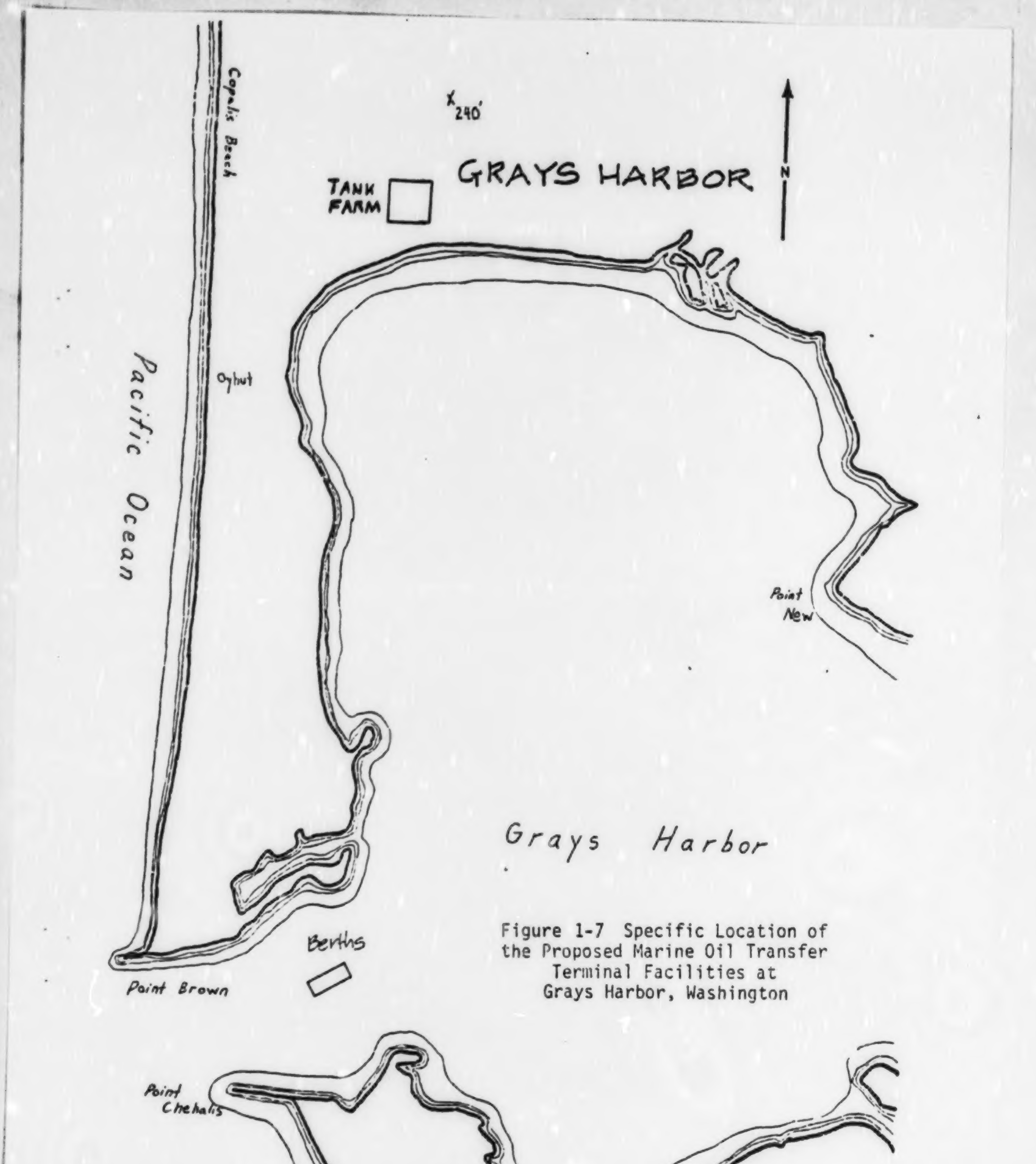
Copalis Beach
x 240'
GRAYS HARBOR
N
TANK FARM
Pacific Ocean
Oyhut
Point New
Grays Harbor
Berths
Point Brown
Point Chehalis
Westport
1 0 1 2
MILES
x 40'
x 60'

Figure 1-7 Specific Location of the Proposed Marine Oil Transfer Terminal Facilities at Grays Harbor, Washington

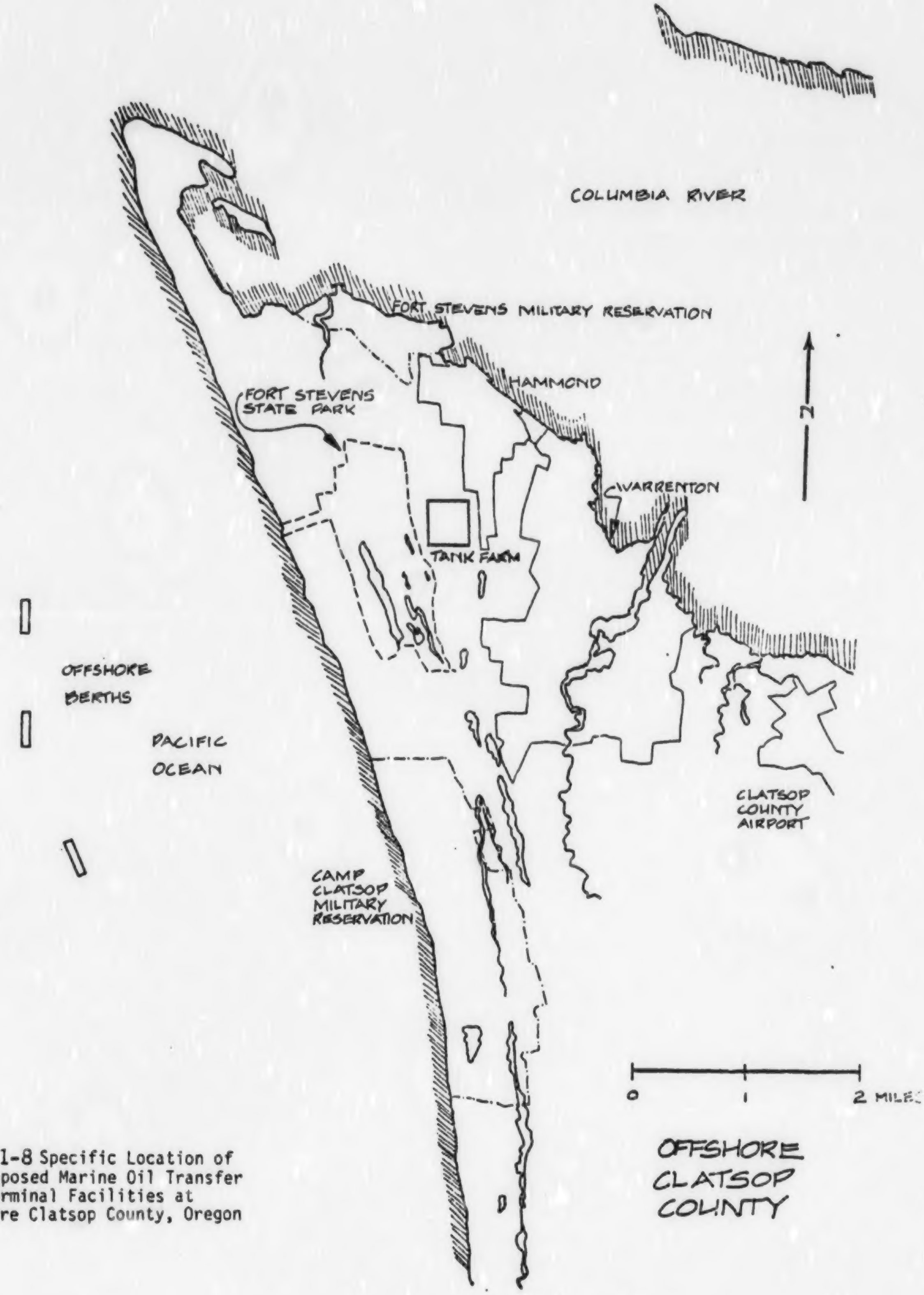
COLUMBIA RIVER
FORT STEVENS MILITARY RESERVATION
HAMMOND
FORT STEVENS STATE PARK
N
WARRENTON
TANK FARM
OFFSHORE BERTHS
PACIFIC OCEAN
CLATSOP COUNTY AIRPORT
CAMP CLATSOP MILITARY RESERVATION
0
1
2 MILE
OFFSHORE CLATSOP COUNTY

Figure 1-8 Specific Location of the Proposed Marine Oil Transfer Terminal Facilities at Offshore Clatsop County, Oregon

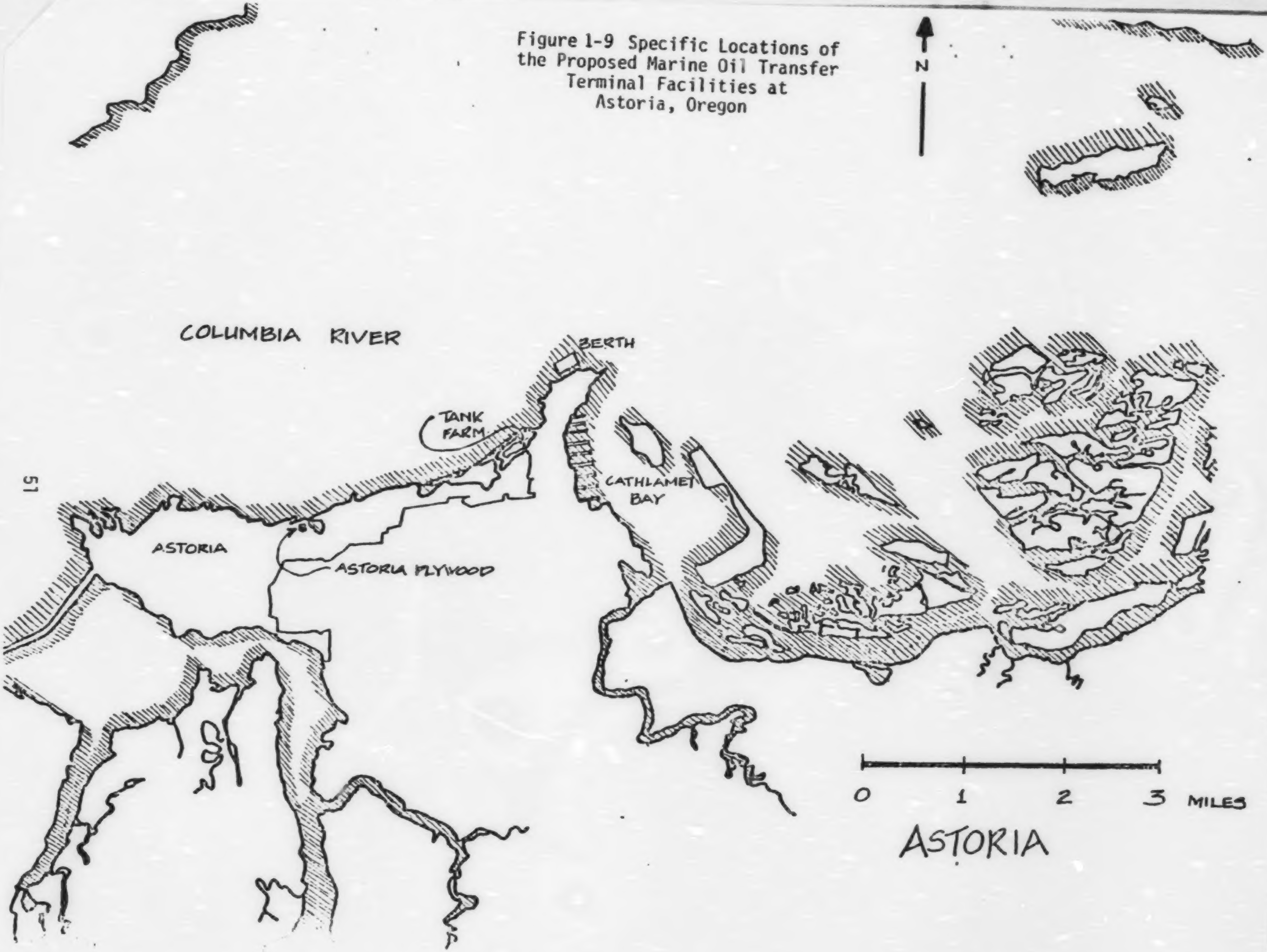
N
COLUMBIA RIVER
BERTH
TANK FARM
CATHLAMET BAY
ASTORIA
ASTORIA PLYWOOD
0
1
2
3 MILES
ASTORIA

Figure 1-9 Specific Locations of the Proposed Marine Oil Transfer Terminal Facilities at Astoria, Oregon

TABLE 1

TANKER FLEET REQUIREMENTS

SCENARIO	TANKER SIZE	NUMBER REQUIRED	ANNUAL PORT CALLS
SCENARIO I	165,000 DWT	6	207
	120,000 DWT	3	103
	80,000 DWT	2	69
SUB-SCENARIO IA	120,000 DWT	5	172
	80,000 DWT	5	172
	76,000 DWT	3	103
	70,000 DWT	6	207
SCENARIO II	165,000 DWT	6	207
	150,000 DWT	2	69
	130,000 DWT	2	69
	120,000 DWT	3	103
	80,000 DWT	2	69
SUB-SCENARIO IIA	120,000 DWT	5	172
	80,000 DWT	5	172
	76,000 DWT	3	103
	70,000 DWT	10	345
	62,000 DWT	3	103
	53,000 DWT	1	35
	52,000 DWT	1	34
	50,000 DWT	1	35
	49,000 DWT	1	34

TABLE 2

APPLICABLE AMBIENT STANDARDS

UG/M^3

STANDARD	NATIONAL PRIMARY	NATIONAL SECONDARY	WASH STATE	OLYMPIC APCA	NORTHWEST APCA	OREGON STATE
SULFUR DIOXIDE						
ANNUAL AVERAGE +	80		60	60	53	60
24-HOUR MAXIMUM #	365		260	260	260	260
3-HOUR MAXIMUM #		1300				1300
1-HOUR MAXIMUM #			1048	1048	1048	
(TWICE PER WEEK)			655	655	655	
5-MINUTE MAXIMUM #					2096	
TOTAL SUSPENDED PARTICULATE						
ANNUAL GEOMETRIC MEAN +	75	60	60		60	60
24-HOUR MAXIMUM #	260	150	150		150	150
(15% PER MONTH)						100
CARBON MONOXIDE						
3-HOUR MAXIMUM #	10*	10*	10*		10*	10*
1-HOUR MAXIMUM #	40*	40*	40*		40*	40*
PHOTOCHEMICAL OXIDENT						
1-HOUR MAXIMUM #	160	160	160		160	160
HYDROCARBONS						
3-HOUR MAXIMUM # (6:00AM TO 9:00AM)	160	160	160		160	160
NITROGEN DIOXIDE						
ANNUAL AVERAGE +	100	100	100		100	100

+NEVER TO BE EXCEEDED

#NOT TO BE EXCEEDED MORE THAN ONCE PER YEAR

* MG/M^3

TABLE 3

AIR QUALITY MONITERING SUMMARY BY SITE

1975-1976

POLLUTANT/STANDARD	NUMBER OF TIMES STANDARD EXCEEDED			
	CHERRY POINT	MARCH POINT	PORT ANGELES	ASTORIA
TOTAL SUSPENDED PARTICULATE				
24-HOUR MAXIMUM			3(1)	
ANNUAL			x(1)	
SULFUR DIOXIDE				
5-MINUTE MAXIMUM	6(2)	40+(2)		
1-HOUR MAXIMUM	1(1)	8(1); 5(2)	24(1)	
3-HOUR MAXIMUM			2(4)	
24-HOUR MAXIMUM		2(1,3)	7(1); 3(3)	
ANNUAL	*			

(1) STATE AND LOCAL

(2) LOCAL

(3) NATIONAL PRIMARY

(4) NATIONAL SECONDARY

* LESS THAN 1 UG/M^3 BELOW THE STATE AND LOCAL STANDARD

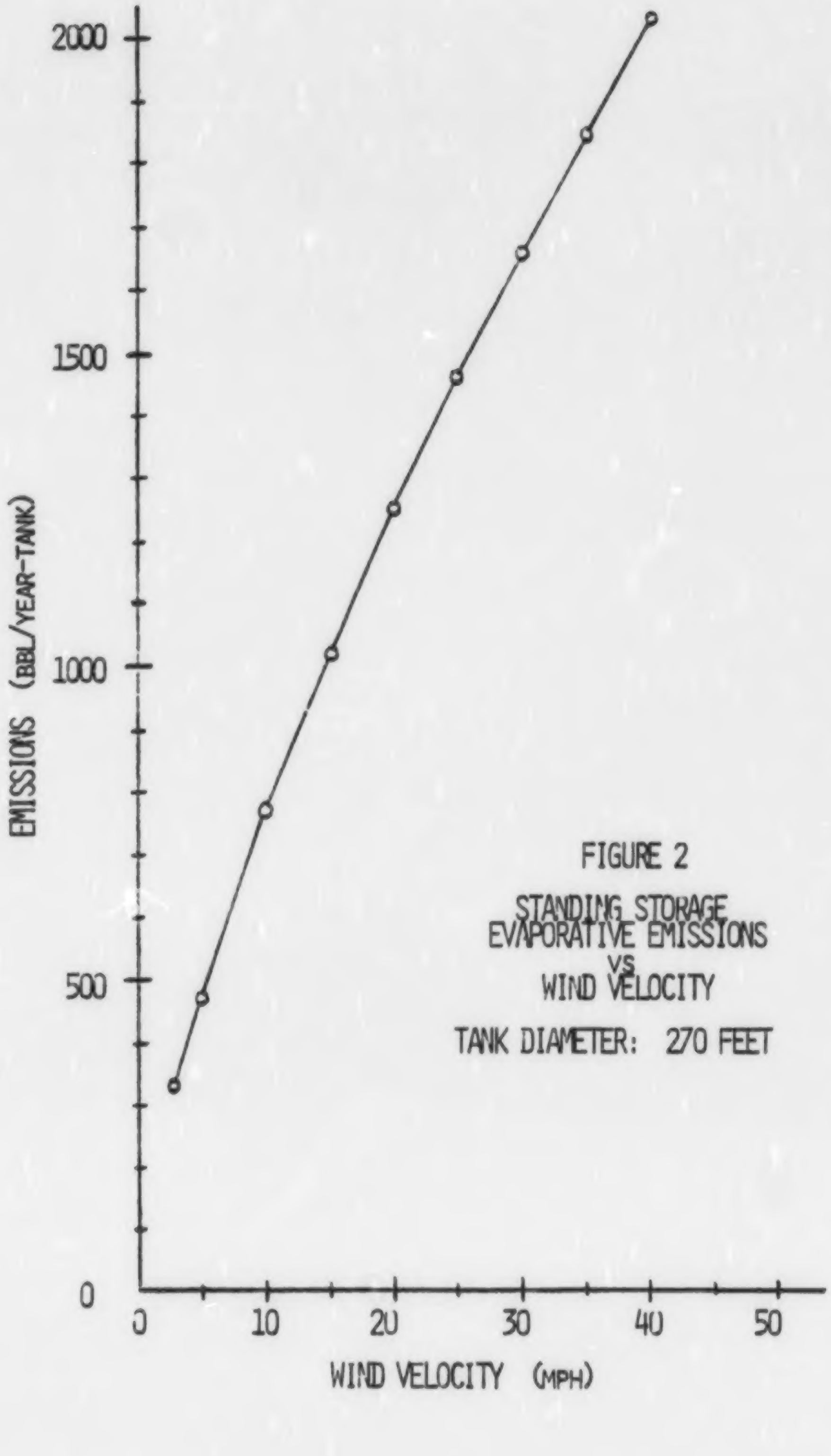

FIGURE 2

STANDING STORAGE
EVAPORATIVE EMISSIONS
VS
WIND VELOCITY

TANK DIAMETER: 270 FEET

TABLE 4

ANNUAL STORAGE TANK EMISSIONS

BARRELS PER YEAR PER TANK
HYDROCARBONS

SITE	AVERAGE ANNUAL WIND SPEED*, mph	STANDING STORAGE EMISSIONS	WITHDRAWAL EMISSIONS	TOTAL EMISSIONS
CHERRY POINT	7	598	55	653
MARCH POINT	8	657	55	712
BURROWS BAY	8	657	55	712
PORT ANGELES	8	657	55	712
OFFSHORE COPALIS	12	872	55	927
COPALIS BEACH	12	872	55	927
GRAYS HARBOR	10	768	55	823
OFFSHORE CLATSOP	12	872	55	927
ASTORIA	6	537	55	592

* Estimated from Climatological Handbook data(18)

TABLE 5

ANNUAL HYDROCARBON EMISSIONS FOR STORAGE AND TRANSFER OPERATIONS

SITE	SCENARIO I		SCENARIO II	
	BBL/YEAR	TONS/YEAR	BBL/YEAR	TONS/YEAR
CHERRY POINT	7483	694	10195	946
MARCH POINT	8132	755	11080	1028
BURROWS BAY	8132	755	11081	1028
PORT ANGELES	8132	755	11080	1028
OFFSHORE COPALIS	10497	974	14305	1328
COPALIS BEACH	10497	974	14305	1328
GRAYS HARBOR	9353	868	12745	1183
OFFSHORE CLATSOP	10497	974	14305	1328
ASTORIA	6182	632	9280	861

TABLE 6

FUEL CONSUMPTION RATES (BBL/HOUR)*

VESSEL	OPERATING MODE			
	CRUISE	MANEUVER	IDLE	OFFLOAD
165,000 DWT	33.4	20.6	4.4	37.3
150,000 DWT	40.0	24.7	5.0	39.1
130,000 DWT	38.7	23.9	4.8	37.8
120,000 DWT	37.3	23.0	4.4	31.2
80,000 DWT	30.2	18.1	2.4	18.4
76,000 DWT	27.1	16.2	2.2	16.5
70,000 DWT	26.6	15.9	2.1	16.2
62,000 DWT	25.9	15.5	2.1	15.8
53,000 DWT	24.9	14.9	2.0	15.2
52,000 DWT	24.8	14.9	2.0	15.1
50,000 DWT	24.7	14.8	2.0	15.0
49,000 DWT	24.6	14.7	2.0	15.0

	AVERAGE
TUGBOAT	1.3
(OFFSHORE SITES)	1.0

---

*BASED ON A DENSITY OF 344.4 LB/BBL (19)

TABLE 7

EMISSION FACTOR (LB/BBL FUEL FIRED)

POLLUTANT	VESSEL	
	TANKER	TUGBOAT
SULFUR DIOXIDE (SO_2)	10.05 *	1.73 +
NITROGEN OXIDES (NO_x)	4.36	9.31
PARTICULATES (PART)	0.966	4.61
HYDROCARBONS (HC)	0.134	5.70
CARBON MONOXIDE (CO)	0.084	2.53
ALDEHYDES (HCHO)	0.084	0.425
ORGANIC ACIDS (OA)	NO DATA	1.30

* Based on 1.5% sulfur in fuel

+ Based on 0.25% sulfur in fuel

TABLE 8A

SO_2 EMISSION RATES (LB/HOUR)

VESSEL	OPERATING MODE			
	CRUISE	MANEUVER	IDLE	OFFLOAD
165,000 DWT	335.7	207.0	44.2	318.7*
150,000 DWT	402.0	248.2	50.2	334.0*
130,000 DWT	388.9	240.2	48.2	380.0
120,000 DWT	374.9	231.2	44.2	266.6* (313.6)
80,000 DWT	303.5	181.9	24.1	184.9
76,000 DWT	272.4	162.8	22.1	165.8
70,000 DWT	267.3	159.8	21.1	162.8
62,000 DWT	260.3	155.8	21.1	158.8
53,000 DWT	250.2	149.7	20.1	152.8
52,000 DWT	249.2	149.7	20.1	151.8
50,000 DWT	248.2	148.7	20.1	150.8
49,000 DWT	247.2	147.7	20.1	150.8
	AVERAGE			
TUGBOAT	2.18			
(OFFSHORE SITES)	1.65			

*REDUCED BY 15% - INERTING SYSTEM IN OPERATION

( ) NON-INERTING 120,000 DWT TANKER

TABLE 8B

NO_X EMISSION RATES (LB/HOUR)

VESSEL	OPERATING MODE			
	CRUISE	MANEUVER	IDLE	OFFLOAD
165,000 DWT	145.6	89.8	19.2	138.2*
150,000 DWT	174.4	107.7	21.8	144.9*
130,000 DWT	168.7	104.2	20.9	164.8
120,000 DWT	162.6	100.3	19.2	115.6* (136.0)
80,000 DWT	131.7	78.9	10.5	80.2
76,000 DWT	118.2	70.6	9.6	71.9
70,000 DWT	116.0	69.3	9.2	70.6
62,000 DWT	112.9	67.6	9.2	68.9
53,000 DWT	108.6	65.0	8.7	66.3
52,000 DWT	108.1	65.0	8.7	65.8
50,000 DWT	107.7	64.5	8.7	65.4
49,000 DWT	107.3	64.1	8.7	65.4
	AVERAGE			
TUGBOAT	11.75			
(OFFSHORE SITES)	8.87			

*REDUCED BY 15% - INERTING SYSTEM IN OPERATION

( ) NON-INERTING 120,000 DWT TANKER

TABLE 8C
PARTICULATE EMISSION RATES (LB/HOUR)

VESSEL	OPERATING MODE			
	CRUISE	MANEUVER	IDLE	OFFLOAD
165,000 DWT	32.3	19.9	4.3	30.6*
150,000 DWT	38.6	23.9	4.8	32.1*
130,000 DWT	37.4	23.1	4.6	36.5
120,000 DWT	36.0	22.2	4.3	25.6* (30.1)
80,000 DWT	29.2	17.5	2.3	17.8
76,000 DWT	26.2	15.6	2.1	15.9
70,000 DWT	25.7	15.4	2.0	15.6
62,000 DWT	25.0	15.0	2.0	15.3
53,000 DWT	24.1	14.4	1.9	14.7
52,000 DWT	24.0	14.4	1.9	14.6
50,000 DWT	23.9	14.3	1.9	14.5
49,000 DWT	23.8	14.2	1.9	14.5

	AVERAGE
TUGBOAT	5.82
(OFFSHORE SITES)	4.39

*REDUCED BY 15% - INERTING SYSTEM IN OPERATION

( ) NON-INERTING 120,000 DWT TANKER

TABLE 8D
HYDROCARBON EMISSION RATES (LB/HOUR)

VESSEL	OPERATING MODE			
	CRUISE	MANEUVER	IDLE	OFFLOAD
165,000 DWT	4.5	2.8	0.6	4.2*
150,000 DWT	5.4	3.3	0.7	4.4*
130,000 DWT	5.2	3.2	0.6	5.1
120,000 DWT	5.0	3.1	0.6	3.6* (4.2)
80,000 DWT	4.0	2.4	0.3	2.5
76,000 DWT	3.6	2.2	0.3	2.2
70,000 DWT	3.6	2.1	0.3	2.2
62,000 DWT	3.5	2.1	0.3	2.1
53,000 DWT	3.3	2.0	0.3	2.0
52,000 DWT	3.3	2.0	0.3	2.0
50,000 DWT	3.3	2.0	0.3	2.0
49,000 DWT	3.3	2.0	0.3	2.0

	AVERAGE
TUGBOAT	7.19
(OFFSHORE SITES)	5.43

*REDUCED BY 15% - INERTING SYSTEM IN OPERATION

( ) NON-INERTING 120,000 DWT TANKER

TABLE 8E

CO EMISSION RATES (LB/HOUR)

VESSEL	OPERATING MODE			
	CRUISE	MANEUVER	IDLE	OFFLOAD
165,000 DWT	2.8	1.7	0.4	2.6*
150,000 DWT	3.4	2.1	0.4	2.8*
130,000 DWT	3.3	2.0	0.4	3.2
120,000 DWT	3.1	1.9	0.4	2.2* (2.6)
80,000 DWT	2.5	1.5	0.2	1.5
76,000 DWT	2.3	1.4	0.2	1.4
70,000 DWT	2.2	1.3	0.2	1.4
62,000 DWT	2.2	1.3	0.2	1.3
53,000 DWT	2.1	1.3	0.2	1.3
52,000 DWT	2.1	1.3	0.2	1.3
50,000 DWT	2.1	1.2	0.2	1.3
49,000 DWT	2.1	1.2	0.2	1.3

	AVERAGE
TUGBOAT	3.19
(OFFSHORE SITES)	2.41

*REDUCED BY 15% - INERTING SYSTEM IN OPERATION

( ) NON INERTING 120,000 DWT TANKER

TABLE 8F
ALDEHYDES EMISSION RATES (LB/HOUR)

VESSEL	OPERATING MODE			
	CRUISE	MANEUVER	IDLE	OFFLOAD
165,000 DWT	2.8	1.7	0.4	2.6*
150,000 DWT	3.4	2.1	0.4	2.8*
130,000 DWT	3.3	2.0	0.4	3.2
120,000 DWT	3.1	1.9	0.4	2.2* (2.6)
80,000 DWT	2.5	1.5	0.2	1.5
76,000 DWT	2.3	1.4	0.2	1.4
70,000 DWT	2.2	1.3	0.2	1.4
62,000 DWT	2.2	1.3	0.2	1.3
53,000 DWT	2.1	1.3	0.2	1.3
52,000 DWT	2.1	1.3	0.2	1.3
50,000 DWT	2.1	1.2	0.2	1.3
49,000 DWT	2.1	1.2	0.2	1.3

	AVERAGE
TUGBOAT	0.54
(OFFSHORE SITES)	0.40

*REDUCED BY 15% - INERTING SYSTEM IN OPERATION

( ) NON-INERTING 120,000 DWT TANKER

TABLE 8G

ORGANIC ACID EMISSION RATES (LB/HOUR)

VESSEL	OPERATING MODE			
	CRUISE	MANEUVER	IDLE	OFFLOAD
165,000 DWT	-	-	-	-
150,000 DWT	-	-	-	-
130,000 DWT	-	-	-	-
120,000 DWT	-	-	-	-
80,000 DWT	-	-	-	-
76,000 DWT	-	-	-	-
70,000 DWT	-	-	-	-
62,000 DWT	-	-	-	-
53,000 DWT	-	-	-	-
52,000 DWT	-	-	-	-
50,000 DWT	-	-	-	-
49,000 DWT	-	-	-	-

	AVERAGE
TUGBOAT	1.64
(OFFSHORE SITES)	1.24

TABLE 9

BALLASTING EMISSIONS

HYDROCARBONS

TANKER SIZE	TOTAL EMISSIONS +		EMISSION RATE LBS/HR
	(BBL)	(LBS)*	
130,000 DWT	89.5	16607	4152
120,000 DWT	82.6	13330	3332
80,000 DWT	55.1	10220	2555
76,000 DWT	39.9	7405	1851
70,000 DWT	36.3	6729	1682
62,000 DWT	32.9	6105	1526
53,000 DWT	29.4	5464	1366
52,000 DWT	28.7	5329	1332
50,000 DWT	26.8	4981	1245
49,000 DWT	26.1	4846	1212

*BASED ON 185.6 LBS/BBL

+FOR BALLASTING 20% OF THE DEAD WEIGHT TONNAGE

TABLE 10

EVAPORATION RATES AND HOURLY VENTING EMISSION RATES FOR NON-INERTING TANKERS

HYDROCARBONS

TANKER SIZE	EVAPORATION RATE (BBL/HOUR) (VOLUME OF GAS)	EMISSION RATE (LB/HOUR)
130,000 DWT	3819	390
120,000 DWT	3525	360
80,000 DWT	2350	240
76,000 DWT	1700	174
70,000 DWT	1550	158
62,000 DWT	1400	143
53,000 DWT	1255	128
52,000 DWT	1225	125
50,000 DWT	1145	117
49,000 DWT	1115	114

TABLE 11A
PURGING EMISSIONS (LBS)*
CELLS PURGED SIMULTANEOUSLY
HYDROCARBONS

	VESSEL SIZE		
	165,000 DWT	150,000 DWT	120,000 DWT
FIRST HOUR	8,437	8,399	8,295
THREE HOURS	23,141	22,837	22,030
SEVEN HOURS	45,516	44,226	40,937

*INERT GAS INPUT AT 10,000 CFM

TABLE 11B

PURGING EMISSIONS (LBS)*

CELLS PURGED SEQUENTIALLY

HYDROCARBONS

	VESSEL SIZE		
	165,000 DWT	150,000 DWT	120,000 DWT
FIRST HOUR	6,779	6,611	6,179
THREE HOURS	12,903	12,150	10,401
SEVEN HOURS	24,153	23,984	21,428

*INERT GAS INPUT AT 10,000 CFM

TABLE 12A

OPERATION PROCEDURES FOR TANKERS WITH INERTING SYSTEMS AND SEGREGATED BALLAST

PROCEDURE	POWER MODE	TIME	SOURCE OF EMISSIONS	OTHER ACTIVITIES WHICH MIGHT OCCUR
DELAY	IDLE	UP TO 8 HOURS	COMBUSTION	
MANEUVERING AND MOORING	MANEUVER	5 HOURS	COMBUSTION	
OFFLOADING	OFFLOAD	24 HOURS	COMBUSTION	INERTING, BALLASTING
SERVICING	IDLE	3.5 HOURS	COMBUSTION FUGITIVE	INERTING, BALLASTING, FUELING, PURGING
DEBERTHING AND DEPARTING	MANEUVER	3.5 HOURS	COMBUSTION FUGITIVE	INERTING, BALLASTING, PURGING

TABLE 12B

OPERATING PROCEDURES FOR TANKERS WITHOUT INERTING SYSTEMS AND COMPLETELY SEGREGATED BALLAST

PROCEDURE	POWER MODE	TIME	SOURCE OF EMISSIONS	OTHER ACTIVITIES WHICH MIGHT OCCUR
DELAY	IDLE	UP TO 8 HOURS	COMBUSTION	
MANEUVERING AND MOORING	MANEUVER	5 HOURS	COMBUSTION	
OFFLOADING	OFFLOAD	24 HOURS	COMBUSTION	BALLASTING
SERVICING	IDLE	3.5 HOURS	COMBUSTION FUGITIVE	BALLASTING, FUELING, VENTING
DEBERTHING AND DEPARTING	MANEUVER	3.5 HOURS	COMBUSTION FUGITIVE	BALLASTING, VENTING

TABLE 13

EMISSIONS PER PORT CALL (LBS)

POLLUTANT	TANKER SIZE							
	165,000 DWT		150,000 DWT		130,000 DWT		120,000 DWT	
	INLAND	OFFSHORE	INLAND	OFFSHORE	INLAND	OFFSHORE	INLAND	OFFSHORE
SO_2	9814	9779	10558	10542	11579	11563	8751* (9879)	8735* (9863)
NO_X	4624	4437	4856	4770	5298	5211	4071* (4561)	3984* (4474)
PART	1134	1041	1158	1115	1255	1212	984* (1042)	940* (1048)
HC	373	259	322	269	337	284	300* (314)	247* (261)
CO	188	138	169	146	178	155	153* (163)	130* (140)
HCHO	98	89	102	98	111	106	86* (96)	82* (92)
ORGANIC ACIDS	56	30	42	30	42	30	42	30
FUGITIVE HC	45516* 24153+	45516* 24153+	44226* 23984+	44226* 23984+	2730	2730	40937* 21428 + (2520)	40937* 21428 + (2520)
FUGITIVE HC EXCLUDING BALLASTING AND PURGING	0*+	0*+	0*+	0*+	2730	2730	0*+ (2520)	0*+ (2520)

*EQUIPPED WITH INERTING SYSTEM - SIMULTANEOUS PURGING

+EQUIPPED WITH INERTING SYSTEM - SEQUENTIAL PURGING

( ) NON-INERTING 120,000 DWT TANKER

TABLE 13 (CONT)

EMISSIONS PER PORT CALL (LBS)

POLLUTANT	TANKER SIZE							
	80,000 DWT		76,000 DWT		70,000 DWT		62,000 DWT	
	INLAND	OFFSHORE	INLAND	OFFSHORE	INLAND	OFFSHORE	INLAND	OFFSHORE
SO_2	6202	6204	5566	5568	5461	5463	5331	5333
NO_X	2874	2887	2598	2611	2552	2565	2497	2510
PART	692	698	629	635	619	625	609	615
HC	205	213	196	204	195	203	192	200
CO	104	108	101	105	100	104	98	102
HCHO	59	60	56	57	55	56	53	54
ORGANIC ACIDS	28	30	28	30	28	30	28	30
FUGITIVE HC	1680	1680	1218	1218	1106	1106	1001	1001
FUGITIVE HC EXCLUDING BALLASTING	1680	1680	1218	1218	1106	1106	1001	1001

TABLE 13 (CONT)

EMISSIONS PER PORT CALL (LBS)

POLLUTANT	TANKER SIZE							
	53,000 DWT		52,000 DWT		50,000 DWT		49,000 DWT	
	INLAND	OFFSHORE	INLAND	OFFSHORE	INLAND	OFFSHORE	INLAND	OFFSHORE
SO_2	5127	5129	5103	5105	5071	5073	5062	5064
NO_X	2409	2422	2397	2410	2383	2396	2380	2393
PART	588	594	586	592	583	589	582	588
HC	189	197	189	197	189	197	189	197
CO	98	102	98	102	97	101	97	101
HCHO	53	54	53	54	52	53	52	53
ORGANIC ACIDS	28	30	28	30	28	30	28	30
FUGITIVE HC	896	896	875	875	819	819	798	798
FUGITIVE HC EXCLUDING BALLASTING	896	896	875	875	819	819	798	798

TABLE 14

TOTAL ANNUAL SHIPPING EMISSIONS (TONS)

POLLUTANT	SCENARIO I		SUB-SCENARIO IA	SCENARIO II		SUB-SCENARIO IIA
	INLAND	OFFSHORE		INLAND	OFFSHORE	
SO_2	1699	1695	2196	2463	2457	3198
NO_X	795	772	1020	1146	1117	1500
PART	194	182	247	277	262	361
HC	61	47	75	84	66	111
CO	31	25	38	42	35	56
HCHO	17	16	21	24	22	31
ORGANIC ACIDS	9	6	10	12	8	15
FUGITIVE HC	6224 * 3340 +	6224 * 3340+	1864* 1191 +	7844 * 4262 +	7844* 4262 +	2050 * 1377 +
FUGITIVE HC EXCLUDING PURGING AND BALLASTING	101	101	450	195	195	637

*SIMULTANEOUS PURGING +SEQUENTIAL PURGING

TABLE 15

AVERAGE HOURLY EMISSION RATES (LBS/HOUR)
FOR SHIPPING OPERATIONS

POLLUTANT	SCENARIO I		SUB-SCENARIO IA	SCENARIO II		SUB-SCENARIO IIA
	INLAND	OFFSHORE		INLAND	OFFSHORE	
SO_2	388.0	387.0	501.0	562.0	561.0	730.0
NO_X	182.0	176.0	233.0	261.5	255.0	343.0
PART	44.0	41.0	56.0	63.5	60.0	82.0
HC	14.0	10.5	17.0	19.0	15.0	25.0
CO	7.0	5.5	8.5	9.5	8.0	13.0
HCHO	4.0	3.5	5.0	5.5	5.0	7.0
ORGANIC ACIDS	2.0	1.5	2.5	2.5	2.0	3.5
FUGITIVE HC	1421* 763+	1421 * 763 +	426 * 272 +	1791* 973+	1791* 973 +	468* 314+
FUGITIVE HC EXCLUDING PURGING AND BALLASTING	23.0	23.0	103.0	44.5	44.5	145.5

*SIMULTANEOUS PURGING +SEQUENTIAL PURGING

TABLE 16
SHORT TERM WORST CASE EMISSIONS (LBS/HOUR) FOR AT-BERTH SHIPPING OPERATIONS

POLLUTANT	SCENARIO I		SUB-SCENARIO IA	SCENARIO II		SUB-SCENARIO IIA
	INLAND	OFFSHORE		INLAND	OFFSHORE	
SO_2	1265	1271	1348	1583	1592	1660
NO_X	549	584	585	687	731	720
PART	121	139	129	152	174	159
HC	17	38	18	21	48	22
CO	11	20	11	13	25	14
HCHO	11	12	11	13	15	14
ORGANIC ACIDS	-	5	-	-	6	-
FUGITIVE HC	8437* 6779+ (23141)* (12903)+	8437* 6779+ (23141)* (12903)+	16590* 12358+ (44060)* (20802)+	8437* 6779+ (23141)* (12903)+	8437* 6779+ (23141)* (12903)+	16590* 12358+ (44060)* (20302)+
FUGITIVE HC EXCLUDING PURGING AND BALLASTING	360	360	720	390	390	720

*SIMULTANEOUS PURGING +SEQUENTIAL PURGING () LBS PER 3-HOURS

TABLE 17

24-HOUR WORST CASE EMISSIONS (LBS/24 HOURS) FOR AT-BERTH SHIPPING OPERATIONS

POLLUTANT	SCENARIO I		SUB-SCENARIO IA	SCENARIO II		SUB-SCENARIO IIA
	INLAND	OFFSHORE		INLAND	OFFSHORE	
SO_2	26579	26628	28739	32280	32320	33303
NO_X	11905	12167	12832	14539	14750	15096
PART	2748	2878	2952	3380	3484	3504
HC	605	766	630	787	916	820
CO	330	401	345	424	481	441
HCHO	237	249	254	291	300	304
ORGANIC ACIDS	57	94	56	82	112	85
FUGITIVE HC	172906* 91162+	172906* 91162+	88132* 49114+	172906* 91162+	172906* 91162+	89517* 50499+
FUGITIVE HC EXCLUDING PURGING AND BALLASTING	5040	5040	11298	5040	5040	12683

*SIMULTANEOUS PURGING +SEQUENTIAL PURGING

TABLE 18A
FREQUENCY OF OCCURRENCE OF SO_2 EMISSIONS
HOURLY EMISSIONS
SCENARIO I - INLAND PORT

EMISSIONS (LBS/HR)	OCCURRENCES (HRS/YR)	FREQUENCY (%)
0	1120	12.8
1-99	285	3.2
100-199	653	7.5
200-299	1149	13.1
300-399	1919*	21.9*
400-499	594	6.8
500-599	1441	16.5
600-699	687	7.8
700-799	372	4.3
800-899	327	3.7
900-999	131	1.5
1000-1099	37	0.4
1100-1199	37	0.4
1200-1299	8+	0.09+
1300-1399		
1400-1499		
1500-1599		

*AVERAGE CASE

+WORST CASE

TABLE 18B

FREQUENCY OF OCCURRENCE OF SO_2 EMISSIONS

3-HOUR AVERAGE EMISSIONS

SCENARIO I - INLAND PORT

EMISSIONS (LBS/HR)	OCCURRENCES PER YEAR	FREQUENCY (%)
0-9	943	10.8
10-99	325	3.7
100-199	871	9.9
200-299	1092	12.5
300-399	1811 *	20.7*
400-499	872	10.0
500-599	1244	14.2
600-699	729	8.3
700-799	421	4.8
800-899	264	3.0
900-999	125	1.4
1000-1099	42	0.5
1100-1199	19	0.2
1200-1299	2+	0.02+
1300-1399		
1400-1499		
1500-1599		

*AVERAGE CASE
+WORST CASE

TABLE 18C

FREQUENCY OF OCCURRENCE OF SO_2 EMISSIONS

24-HOUR AVERAGE EMISSIONS

SCENARIO I - INLAND PORT

EMISSIONS (LBS/HR)	OCCURRENCES PER YEAR	FREQUENCY (%)
0-9	233	2.7
10-99	572	6.5
100-199	1024	11.7
200-299	1567	17.9
300-399	1599*	18.2*
400-499	1450	16.6
500-599	1078	12.3
600-699	680	7.8
700-799	365	4.2
800-899	137	1.6
900-999	49	0.6
1000-1099	6+	0.07+
1100-1199		
1200-1299		
1300-1399		
1400-1499		
1500-1599		

*AVERAGE CASE

+WORST CASE

TABLE 18D
FREQUENCY OF OCCURRENCE OF SO_2 EMISSIONS
HOURLY EMISSIONS
SCENARIO II - INLAND PORT

EMISSIONS (LBS/HR)	OCCURRENCES (HRS/YR)	FREQUENCY (%)
0	401	4.6
1-99	191	2.2
100-199	322	3.7
200-299	774	8.8
300-399	1458	16.6
400-499	567	6.5
500-599	1496 *	17.1 *
600-699	1229	14.0
700-799	577	6.6
800-899	700	8.0
900-999	489	5.6
1000-1099	249	2.8
1100-1199	164	1.9
1200-1299	99	1.1
1300-1399	25	0.3
1400-1499	13	0.15
1500-1599	6 +	0.06 +

*AVERAGE CASE

+WORST CASE

TABLE 18E

FREQUENCY OF OCCURRENCE OF SO_2 EMISSIONS

3-HOUR AVERAGE EMISSIONS

SCENARIO II - INLAND PORT

EMISSIONS (LBS/HR)	OCCURRENCES PER YEAR	FREQUENCY (%)
0-9	314	3.6
10-99	183	2.1
100-199	478	5.5
200-299	662	7.6
300-399	1330	15.2
400-499	922	10.5
500-599	1394 *	15.9 *
600-699	1052	12.0
700-799	826	9.4
800-899	658	7.5
900-999	423	4.8
1000-1099	251	2.9
1100-1199	148	1.7
1200-1299	76	0.9
1300-1399	25	0.3
1400-1499	12	0.14
1500-1599	6 +	0.07+

*AVERAGE CASE

+WORST CASE

TABLE 18F

FREQUENCY OF OCCURRENCE OF SO_2 EMISSIONS

24-HOUR AVERAGE EMISSIONS

SCENARIO II - INLAND PORT

EMISSIONS (LBS/HR)	OCCURRENCES PER YEAR	FREQUENCY (%)
0-9	25	0.3
10-99	175	2.0
100-199	405	4.6
200-299	825	9.4
300-399	1170	13.4
400-499	1431	16.3
500-599	1416 *	16.2 *
600-699	1190	13.6
700-799	894	10.2
800-899	592	6.8
900-999	371	4.2
1000-1099	167	1.9
1100-1199	66	0.8
1200-1299	27	0.3
1300-1399	6 +	0.07 +
1400-1499		
1500-1599		

*AVERAGE CASE

+WORST CASE

TABLE 19

MAXIMUM PREDICTED HOURLY CONCENTRATIONS UG/M^3

TANKER STACK EMISSIONS
FLAT TERRAIN MODELING
STABILITY B; 5 M/SEC; 0.74 KM

POLLUTANT	SCENARIO I	SUB-SCENARIO	SCENARIO II	SUB-SCENARIO
	INLAND	IA	INLAND	IIA
SO_2	442	471	553	580
NO_x	192	204	240	251
PART	42	45	53	55
HC	6	6	7	8
CO	4	4.	4	5
HCHO	4	4	4	5
ORGANIC ACIDS	---	---	---	---

EMISSION RATES FROM TABLE B - APPENDIX II

TABLE 20

PREDICTED HOURLY CONCENTRATIONS UG/M^3

TANKER STACK EMISSIONS

FLAT TERRAIN MODELING

STABILITY D; 7 M /SEC; 2.3 KM

POLLUTANT	SCENARIO I	SUB-SCENARIO	SCENARIO II	SUB-SCENARIO
	INLAND	IA	INLAND	IIA
SO_2	269	286	336	353
NO_x	117	123	146	153
PART	26	27	32	34
HC	4	4	4	5
CO	2	2	3	3
HCHO	2	2	3	3
ORGANIC ACIDS	—	—	—	—

EMISSION RATES FROM TABLE B - APPENDIX II

TABLE 21

MAXIMUM PREDICTED HOURLY CONCENTRATIONS UG/M^3
TANKER STACK EMISSIONS

TERRAIN INTERACTION MODELING

STABILITY E; 2.5 M/SEC

SITE	POLLUTANT	SCENARIO I	IA	SCENARIO II	IIA
PORT ANGELES (2.7 KM)	SO_2	817	---	1023	---
	NO_x	355	---	444	---
	TSP	78	---	98	---
BURROWS BAY (1.0 KM)	SO_2	5403	5755	6762	7091
	NO_x	2346	2498	2936	3074
	TSP	515	552	651	678
BURROWS BAY (2.8 KM)	SO_2	1094	1166	1370	1436
	NO_x	475	506	595	623
	TSP	104	112	132	137
MARCH POINT (2.4 KM)	SO_2	1299	1384	1626	1705
	NO_x	564	601	706	739
	TSP	124	133	156	163
CHERRY POINT (2.1 KM)	SO_2	771	821	964	1011
	NO_x	335	356	419	438
	TSP	73	79	93	97

EMISSION RATES FROM TABLE B- APPENDIX II

TABLE 22

MAXIMUM PREDICTED HOURLY CONCENTRATIONS UG/M^3

FUGITIVE TANKER EMISSIONS

HYDROCARBONS

STABILITY E; 2.5 M/SEC

EMISSIONS	TANKER CONFIGURATION	0.5 KM	1.0 KM	5.0 KM	10.0 KM
FUGITIVE HC* (542 GM/SEC)	IN-LINE ALONG	144177	55940	5471	1911
	IN-LINE ACROSS	19107	15804	4382	1758
	GROUPED ALONG	100059	47768	5381	1900
	GROUPED ACROSS	35677	25661	4905	1837
FUGITIVE HC EXCLUDING PURGING & BALLASTING (45.4 GM/SEC)	IN-LINE ALONG	12077	4686	458	160
	IN-LINE ACROSS	1600	1324	367	147
	GROUPED ALONG	8381	4001	451	159
	GROUPED ACROSS	2988	2149	411	154

EMISSION RATES FROM TABLE B -- SCENARIO I -- INLAND

* 3-HOUR AVERAGE EMISSION RATE FOR SEQUENTIAL PURGING

TABLE 23

PREDICTED HOURLY HYDROCARBON CONCENTRATIONS UG/M^3

FUGITIVE TANKER EMISSIONS

STABILITY D; 10 M/SEC

EMISSIONS	TANKER CONFIGURATION	0.5 KM	1.0 KM	5.0 KM	10.0 KM
FUGITIVE HC* (542 GM/SEC)	IN-LINE ALONG	22016	7622	648	239
	IN-LINE ACROSS	4405	3197	580	229
	GROUPED ALONG	17345	6971	643	239
	GROUPED ACROSS	7705	4639	615	235
FUGITIVE HC EXCLUDING PURGING & BALLASTING (45.4 GM/SEC)	IN-LINE ALONG	1844	638	54	20
	IN-LINE ACROSS	369	268	49	19
	GROUPED ALONG	1453	584	54	20
	GROUPED ACROSS	645	389	51	20

EMISSION RATES FROM TABLE B: SCENARIO I - INLAND

* 3-HOUR AVERAGE EMISSION RATE FOR SEQUENTIAL PURGING

TABLE 24

PREDICTED HOURLY HYDROCARBON CONCENTRATIONS UG/M^3

FROM BALLASTING EMISSIONS

STABILITY D; 20 M/SEC

TANKER SIZE	0.5KM	1.0 KM	5.0 KM	10.0 KM
130,000	8369	3364	310	115
120,000	6720	2701	249	92
80,000	5152	2071	191	71
76,000	3728	1498	138	51
70,000	3392	1363	126	47
62,000	3072	1235	114	42
53,000	2752	1106	102	38
52,000	2688	1080	100	37
50,000	2512	1010	93	35
49,000	2488	984	91	34

NOTE: TANKERS ARE GROUPED ALONG WIND

EMISSION RATES FROM TABLE D - APPENDIX II

TABLE 25

PREDICTED HYDROCARBON CONCENTRATIONS ug/m^3
FOR TANK FARM IN CLUSTERED FORMATION

SCENARIO I

METEOROLOGY Stability	 Wind Speed	0.5 km	1.0 km	5.0 km	10.0 km
B	2m/sec	361	122	6	---
B	4m/sec	280	95	4	---
C	3m/sec	538	239	19	5
C	5m/sec	448	200	16	---
C	10m/sec	355	158	13	---
D	3m/sec	775	491	70	27
D	5m/sec	646	410	58	22
D	10m/sec	512	326	46	18
D	20m/sec	410	260	37	14
E	2.5m/sec	937	702	147	56
E	4m/sec	794	595	124	47

Emission rate from Table 5 - APPENDIX II

APPENDIX I

Methodology

Methodology - Table 13

Emissions per Port Call

Use the number of hours of each operation procedure from Tables 12A and 12B in conjunction with emissions rates from Tables 8A-8G, 9, 10, 11A and 11B.

The combustion emissions for any size tanker would be that associated with the following algorithm:

(4 hours of idle) + (5 hours of maneuvering) + (24 hours of offloading) + (3.5 hours of idle) + (3.5 hours of maneuvering)

In addition there would be tugboat emissions as follows:

for inland ports (8.5 hours of emission) x (number of tugs) for offshore ports (24 hours of emissions for one tug)

The fugitive HC emissions would be as follows:

For inerting tankers - (7 hours of purging)

For non-inerting tankers - (7 hours of venting)

The fugitive HC emissions excluding both ballasting and purging would be as follows:

For inerting tankers - none

For non-inerting tankers - (7 hours of venting)

Methodology - Tables 14 and 15
Total Annual and Average Hourly Shipping Emissions

Use the tanker fleets as outlined in Table 1 and the emissions per port call of Table 13.

The total annual emissions for each scenario are the sum of the number of annual port calls for a vessel times its emissions per port call over all vessels utilized for that scenario.

Note that for Scenarios I and II, two of the 120,000 dwt tankers are equipped with inerting systems and one is not. For Sub-scenarios IA and IIA, two of the 120,000 dwt tankers are equipped with inerting systems and three are not.

To obtain Table 15, divide each entry in Table 14 by 8760, the number of hours per year.

Methodology - Table 16
Short Term Worst Case Emissions

Use the emission rates from Tables 8A-8G, 10, 11A and 11B.

The object is to maximize emissions for a reasonably probable situation.

For combustion emissions, each berth is occupied by the largest available tanker that the berth can accomodate. All tankers are offloading simultaneously. The 120,000 dwt tankers are not equipped with inerting systems. The situations then for each scenario are as follows:

Scenario I: 2- 165,000 dwt and 2- 120,000 dwt

Sub-scenario IA: 2- 120,000 dwt, 3 - 80,000 dwt
and 1-76,000 dwt

Scenario II: 2-120,000 dwt, 3-80,000 dwt, 1-76,000 dwt,
1-62,000 dwt and 1-53,000 dwt

The fugitive HC emissions are those associated with one tanker for Scenarios I and II and with two tankers for Sub-scenarios IA and IIA. The specific situations for each scenario are as follows:

Fugitive HC

Scenario I: 1-165,000 dwt tanker purging
Sub-scenario IA: 2-120,000 dwt tankers purging
Scenario II: 1-165,000 dwt tanker purging
Sub-scenario IIA: 2-120,000 dwt tankers purging

Fugitive HC excluding purging and ballasting

Scenario I: 1-120,000 dwt tanker venting
Sub-scenario IA: 2-120,000 dwt tankers venting
Scenario II: 1-130,000 dwt tanker venting
Sub-scenario IIA: 2-120,000 dwt tankers venting

Methodology - Table 17
24-Hour Worst Case Emissions

Use the number of hours of each operating procedures from Tables 12A and 12B in conjunction with emission rates from Tables 8A-8G, 10, 11A and 11B.

For Scenarios I and II, a tanker arrives every 5 hours until all berths are occupied as follows:

Scenario I: 2-165,000 dwt and 2-120,000 dwt
Scenario II: 3-165,000 dwt and 2-120,000 dwt

For Sub-Scenarios IA and IIA, a tanker arrives every 3 hours until all berths are occupied as follows:

Sub-scenario IA: 2-120,000 dwt, 3-80,000 dwt and 1-76,000 dwt

Sub-scenario IIA: 2-120,000 dwt, 3-80,000 dwt, 1-76,000 dwt, 1-62,000 dwt and 1-53,000 dwt

For combustion emissions choose the 24-hour period which maximizes the number of hours of offloading. Also, assume that 120,000 dwt tankers do not have inerting systems.

For fugitive HC emissions choose the 24-hour period which maximizes the number of hours of purging and venting. The specific situation for each scenario is as follows:

Fugitive HC

Scenarios I and II: 2-165,000 dwt tankers purging and 2-120,000 dwt tankers purging.

Sub-scenario IA: 2-120,000 dwt tankers purging, 3-80,000 dwt tankers venting and 1-76,000 dwt tanker venting.

Sub-scenario IIA: 2-120,000 dwt tankers purging, 3-80,000 dwt, 1-76,000 dwt, 1-62,000 dwt and 1-53,000 dwt tankers venting.

Tanker Activity Simulation Model

This simulation model increments time and moves each tanker forward in the current stage of its journey by one hour. The program then determines where each tanker is in that stage of its journey and if appropriate, starts it on the next stage.

The program is designed to use two separate tanker fleets. Tanker fleet "A" operates between the Port of Valdez and a Northwest port. Tanker fleet "B" operates between Valdez and any of several ports on the West Coast. Both fleets are variable as to the number and type of tankers.

The round trip journey for tanker fleet "A" has four stages: port time in Valdez, the trip to the Northwest port, port time at the Northwest port, and the return trip to Valdez. The round trip to and from a West Coast port. For tanker fleet "A" the time required for the trips between ports is a uniform random variable, the minimum of which is the minimum trip time and the mean of which is such that the required number of port calls per year is achieved. For tanker fleet "B" the time required for the round trip to the West Coast port is a uniform random variable, the minimum of which is the minimum trip time to a Northwest port and the maximum of which is an average trip time to a Southern California port.

The program is written with three constraints upon moving a tanker into a berth at port. The first and obvious one is that there must be an empty berth available. It is assumed that there are five berths at Valdez. The number of berths at a Northwest port is variable. The second constraint is based upon the supposition that only one tanker can be moving at a time in the vicinity of the berths. Thus, one tanker cannot begin to enter a berth if another tanker is moving into or out of another berth. The third and final constraint is that tankers enter berth in order of their arrival at the port.

After moving each tanker forward in time by one hour, the program checks to see if any tankers are at the Northwest port. If so, several calculations can be made depending upon what was chosen on the initial control card. The number of berths occupied during that hour can be tabulated and statistics generated as to the frequency of occupation of any number of berths. The total emissions for all tankers in port during that hour can be computed and statistics generated as to the frequency of emission levels. Finally, running average emissions for any time period up to and including the current hour can be computed and statistics generated as to the frequency of occurrence of non-overlapping periods with emissions above a specified level.

The specific inputs to the program are as follows:

First Card:

The number of tankers in fleet "A" = N; The number of tankers in fleet "B" = M the number of berths at the Northwest port; The number of tanker types in fleet "A" the number of hours to run the simulation; the number of hours for running average if desired; quene for non-overlapping mode if desired; specified emission level for non-overlapping mode.

Next "N" cards:

Initialization data for each tanker in fleet "A". Type of tanker; state of its journey; current hour of that stage; final hour of that stage; berth entrance priority for Valdez, berth entrance priority for Northwest port.

Next "M" cards:

Initialization data for each tanker in fleet "B" stage of its journey; current hour of that stage; final hour of that stage; berth entrance priority for Valdez.

Final Cards:

Hourly emission date for each tanker type - 3 cards per tanker type. Emission rate for each hour of port time at the Northwest port.

APPENDIX II

Modeling Study

PTMAX

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TANKER MODELLING FOR MAXIMUM IMPACT

ANALYSIS OF CONCENTRATION AS A FUNCTION OF STABILITY AND WIND SPEED. 1971 VERSION, D. B. TURNER.

 EMISSION RATE (G/SEC) =    1.00, PHY HT (M) =    35.00, STACK TEMP (DEG,K) = 440.00, STACK VEL (M/SEC) =  51.60,
 DIAM (M) =  1.00, VOLUME FLOW (CU M/SEC) =   40.50

   WIND SPEED (M/SEC)   0.5         0.8         1.0         1.5         2.0         2.5         3.0         4.0         5.0

 STABILITY = 1
  MAX CONC (G/CU M)   2.1001E-06 2.4552E-06 2.6265E-06 2.9228E-06 3.1056E-06 3.2335E-06 3.3186E-06
  DIST OF MAX (KM)       1.144      0.944      0.858      0.722      0.643      0.586      0.542
  PLUME HEIGHT (M)     744.9(2)   478.7(2)   390.0(2)   271.6(2)   212.5(2)   177.0      153.3

 STABILITY = 2
  MAX CONC (G/CU M)   8.1327E-07 1.1277E-06 1.3067E-05 1.6753E-06 1.9604E-06 2.1859E-06 2.3637E-06 2.6160E-06 2.7720E-06
  DIST OF MAX (KM)       4.400      2.936      2.434      1.750      1.398      1.183      1.038      0.853      0.740
  PLUME HEIGHT (M)     744.9(2)   478.7(2)   390.0(2)   271.6(2)   212.5(2)   177.0      153.3      123.7      106.0

 STABILITY = 3
  MAX CONC (G/CU M)                                               1.5507E-06 1.7843E-06 1.9786E-06 2.2737E-06 2.4756E-06
  DIST OF MAX (KM)                                                   2.681      2.195      1.876      1.484      1.252
  PLUME HEIGHT (M)                                                 212.5(2)   177.0      153.3      123.7      106.0

 STABILITY = 4
  MAX CONC (G/CU M)   9.3379E-08 1.9149E-07 2.6521E-07 4.4495E-07 6.2451E-07 7.8973E-07 9.3971E-07 1.1997E-06 1.4094E-06
  DIST OF MAX (KM)      96.226     40.575     28.630     15.141     10.047      7.447      5.902      4.171      3.246
  PLUME HEIGHT (M)     744.9(2)   478.7(2)   390.0(2)   271.6(2)   212.5(2)   177.0      153.3      123.7      106.0

 STABILITY = 5
  MAX CONC (G/CU M)                                               1.9720E-06 1.8224E-06 1.7041E-06 1.5124E-06 1.3709E-06
  DIST OF MAX (KM)                                                   6.982      6.381      5.939      5.341      4.936
  PLUME HEIGHT (M)                                                 110.8      105.4      101.2       95.2       90.9

 STABILITY = 6
  MAX CONC (G/CU M)                                               1.5163E-06 1.4074E-06 1.3202E-06 1.1868E-06 1.0874E-06
  DIST OF MAX (KM)                                                  14.345     12.970     11.970     10.586      9.656
  PLUME HEIGHT (M)                                                  97.9       93.4       90.0       84.9       81.4

   WIND SPEED (M/SEC)   7.0         10.0        12.0        15.0        20.0

 STABILITY = 3
  MAX CONC (G/CU M)   2.7014E-05 2.7427E-06 2.7727E-06 2.6877E-06
  DIST OF MAX (KM)       0.992      0.800      0.727      0.654
  PLUME HEIGHT (M)      95.7       70.5       64.6       58.7

 STABILITY = 4
  MAX CONC (G/CU M)   1.6434E-05 1.8883E-06 1.9439E-06 1.9604E-06 1.9006E-06
  DIST OF MAX (KM)       2.323      1.713      1.495      1.287      1.091
  PLUME HEIGHT (M)      85.7       70.5       64.6       58.7       52.7

  (1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST
        LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR.

  (2) THE PLUME IS OF SUFFICIENT HEIGHT THAT EXTREME CAUTION SHOULD BE USED IN INTERPRETING THIS COMPUTATION AS THIS
        STABILITY TYPE MAY NOT EXIST TO THIS HEIGHT. ALSO WIND SPEED VARIATIONS WITH HEIGHT MAY EXERT A DOMINATING
        INFLUENCE.

  (3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS THE POINT OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS
        FROM THE SOURCE.
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PTD15

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      TANKER MODELLING

   CONCENTRATION ESTIMATES. 0BT43.

   CARE SHOULD BE EXERCISED IN THE INTERPRETATION OF THESE CALCULATED CONCENTRATIONS. CONCENTRATION ESTIMATES MAY BE
      EXPECTED TO BE WITHIN A FACTOR OF THREE FOR 1) ALL STABILITIES FOR DISTANCES OF TRAVEL OUT TO A FEW HUNDRED METERS,
      2) NEUTRAL TO MODERATELY UNSTABLE CONDITIONS FOR DISTANCES OUT TO A FEW KILOMETERS, AND 3) UNSTABLE CONDITIONS IN
      THE LOWER 1000 METERS OF THE ATMOSPHERE WITH A MARKED INVERSION ABOVE FOR DISTANCES OUT TO 10 KILOMETERS OR MORE.
       FOR OTHER CONDITIONS THE ESTIMATES BECOME LESS RELIABLE FOR EXTREMES OF STABILITY AND AS TRAVEL DISTANCE INCREASES.

   WIND SPEED =  0.5 M/SEC, STABILITY CLASS =  2,HEIGHT OF MIXING = 1000. METERS, AMBIENT TEMPERATURE = 290.0 DEG K.

     EMISSION  PHYSICAL  STACK GAS STACK GAS  STACK    STACK GAS  BRIGGS   HEIGHT OF  DIST OF
       RATE     HEIGHT     TEMP    VELOCITY  DIAMETER  VOL FLOW    -F-    FINAL RISE FINAL RISE
     (G/SEC)     (M)     (DEG-K)   (M/SEC)     (M)    (M**3/SEC)             (M)        (KM)

        1.00      35.0     440.0     51.60     1.00      40.50     43.10     755.7      0.515

   DISTANCE EFFECTIVE CONCENTRATION SIGY        SIGZ     CHI * U / Q   HOUM  ANDUM
      KM     HEIGHT(M)     G/M**3       M.        M.       SEC/M**3

      0.500     741.8      0.0           82.75     51.09   0.0              4      1.
      1.000     755.7      1.57E-15     154.12    109.30   7.85E-16         4      1.
      1.500     755.7      9.17E-10     221.31    170.53   4.59E-10         4      1.
      2.000     755.7      5.13E-08     285.80    233.82   2.57E-08         4      1.
      2.500     755.7      2.50E-07     348.30    298.68   1.25E-07         4      1.
      3.000     755.7      5.12E-07     409.22    364.41   2.56E-07         4      1.
      3.500     755.7      7.30E-07     468.82    432.03   3.65E-07         4      2.
      4.000     755.7      8.80E-07     527.31    500.20   4.40E-07         4      2.
      4.500     755.7      9.67E-07     584.82    569.19   4.84E-07         4      2.
      5.000     755.7      1.01E-06     641.47    638.94   5.03E-07         4      2.
      6.000     755.7      9.85E-07     752.50    780.42   4.92E-07         4      2.
      7.000     755.7      9.07E-07     860.93    924.22   4.54E-07         4      2.
      8.000     755.7      8.21E-07     967.15   1070.04   4.10E-07         4      3.
      9.000     755.7      7.44E-07    1071.44   1217.64   3.72E-07         4      3.
     10.000     755.7      6.80E-07    1174.01   1366.85   3.40E-07         4      3.
     12.000     755.7      5.80E-07    1374.67   1669.51   2.90E-07         3      0.
     14.000     755.7      5.09E-07    1570.20   1977.14   2.54E-07         3      0.
     16.000     755.7      4.53E-07    1761.33   2284.08   2.27E-07         3      0.
     18.000     755.7      4.09E-07    1948.64   2604.43   2.05E-07         3      0.
     20.000     755.7      3.74E-07    2132.55   2924.62   1.87E-07         3      0.
     25.000     755.7      3.09E-07    2579.57   3735.05   1.55E-07         3      0.
     30.000     755.7      2.65E-07    3011.28   4562.15   1.32E-07         3      0.
     35.000     755.7      2.31E-07    3430.31   5000.00   1.16E-07         3      0.
     40.000     755.7      2.08E-07    3838.48   5000.00   1.04E-07         3      0.
     50.000     755.7      1.72E-07    4627.46   5000.00   8.62E-08         3      0.
     60.000     755.7      1.48E-07    5386.08   5000.00   7.41E-08         3      0.
     70.000     755.7      1.30E-07    6119.50   5000.00   6.52E-08         3      0.
     80.000     755.7      1.17E-07    6831.37   5000.00   5.84E-08         3      0.
     90.000     755.7      1.06E-07    7524.43   5000.00   5.30E-08         3      0.
    100.000     755.7      9.73E-08    8200.80   5000.00   4.86E-08         3      0.
```

PTDIS

```
WIND SPEED =  2.0 M/SEC. STABILITY CLASS =  3.HEIGHT OF MIXING = 5000. METERS. AMBIENT TEMPERATURE = 290.0 DEG K.
 EMISSION  PHYSICAL  STACK GAS STACK GAS  STACK     STACK GAS  BRIGGS    HEIGHT OF  DIST OF
   RATE     HEIGHT     TEMP    VELOCITY  DIAMETER   VOL FLOW    -F-     FINAL RISE FINAL RISE
 (G/SEC)     (M)     (DEG-K)   (M/SEC)     (M)     (M**3/SEC)              (M)        (KM)

   1.00      35.0     440.0     51.60      1.00      40.50     43.10      215.2      0.515
DISTANCE EFFECTIVE CONCENTRATION SIGY       SIGZ    CHI * U / Q   MDUM  ANDUM


  KM     HEIGHT(M)     G/M**3       M.       M.      SEC/M**3
  0.500    211.7     5.03E-14     54.77    32.43    1.01E-13     1    0.
  1.000    215.2     5.16E-08    103.11    61.14    1.03E-07     1    0.
  1.500    215.2     6.31E-07    149.06    88.59    1.26E-06     1    0.
  2.000    215.2     1.23E-06    193.45   115.26    2.50E-06     1    0.
  2.500    215.2     1.49E-06    236.68   141.35    2.99E-06     1    0.
  3.000    215.2     1.49E-06    279.00   167.01    2.98E-06     1    0.
  3.500    215.2     1.38E-06    320.56   192.29    2.76E-06     1    0.
  4.000    215.2     1.24E-06    361.47   217.27    2.48E-06     1    0.
  4.500    215.2     1.10E-06    401.80   241.99    2.20E-06     1    0.
  5.000    215.2     9.76E-07    441.64   266.47    1.95E-06     1    0.
  6.000    215.2     7.70E-07    519.98   314.82    1.54E-06     1    0.
  7.000    215.2     6.17E-07    596.81   362.49    1.23E-06     1    0.
  8.000    216.2     5.03E-07    672.34   409.58    1.01E-06     1    0.
  9.000    215.2     4.18E-07    746.74   456.17    8.36E-07     1    0.
 10.000    215.2     3.52E-07    820.13   502.32    7.05E-07     1    0.
 12.000    215.2     2.60E-07    964.29   593.48    5.21E-07     1    0.
 14.000    215.2     2.01E-07   1105.42   683.34    4.01E-07     1    0.
 16.000    215.2     1.59E-07   1243.98   772.11    3.19E-07     1    0.
 18.000    215.2     1.30E-07   1380.27   859.94    2.60E-07     1    0.
 20.000    215.2     1.08E-07   1514.57   946.93    2.16E-07     1    0.
 25.000    215.2     7.31E-08   1842.77  1161.34    1.46E-07     1    0.
 30.000    215.2     5.30E-08   2161.94  1372.09    1.06E-07     1    0.
 35.000    215.2     4.04E-08   2473.59  1579.84    8.07E-08     1    0.
 40.000    215.2     3.19E-08   2778.81  1785.07    6.37E-08     1    0.
 50.000    215.2     2.14E-08   3373.05  2189.25    4.29E-08     1    0.
 60.000    215.2     1.55E-08   3949.27  2586.53    3.11E-08     1    0.
 70.000    215.2     1.18E-08   4510.51  2974.14    2.36E-08     1    0.
 80.000    215.2     9.33E-09   5058.95  3365.07    1.87E-08     1    0.
 90.000    215.2     7.58E-09   5596.19  3747.83    1.52E-08     1    0.
100.000    215.2     6.24E-09   6123.50  4126.98    1.26E-08     1    0.
```

PTDIS

```
WIND SPEED =  2.0 M/SEC. STABILITY CLASS =  4.HEIGHT OF MIXING = 5000. METERS. AMBIENT TEMPERATURE = 290.0 DEG K.

 EMISSION  PHYSICAL  STACK GAS STACK GAS  STACK    STACK GAS  BRIGGS   HEIGHT OF  DIST OF
   RATE     HEIGHT     TEMP    VELOCITY  DIAMETER  VOL FLOW    -F-    FINAL RISE FINAL RISE
 (G/SEC)     (M)     (DEG-K)   (M/SEC)     (M)    (M**3/SEC)              (M)       (KM)

    1.00      35.0     440.0     51.60      1.00     40.50     43.10     215.2     0.515

DISTANCE EFFECTIVE CONCENTRATION SIGY       SIGZ    CHI * U / Q  HDUM  ANDUM
  KM     HEIGHT(M)     G/M**3      M.        M.       SEC/M**3

  0.500    211.7      0.0            36.15    18.30   0.0            0     0.
  1.000    215.2      1.26E-14       69.13    32.09   2.52E-14       1     0.
  1.500    215.2      6.27E-11       98.55    41.67   1.25E-10       1     0.
  2.000    215.2      2.49E-09      127.95    50.15   4.99E-09       1     0.
  2.500    215.2      1.76E-08      156.60    57.90   3.52E-08       1     0.
  3.000    215.2      5.63E-08      184.64    65.12   1.13E-07       1     0.
  3.500    215.2      1.13E-07      212.19    71.48   2.26E-07       1     0.
  4.000    215.2      1.82E-07      239.32    77.49   3.63E-07       1     0.
  4.500    215.2      2.54E-07      266.07    83.21   5.08E-07       1     0.
  5.000    215.2      3.23E-07      292.48    88.69   6.47E-07       1     0.
  6.000    215.2      4.40E-07      344.45    99.03   8.80E-07       1     0.
  7.000    215.2      5.22E-07      395.43   108.71   1.04E-06       1     0.
  8.000    215.2      5.72E-07      445.55   117.85   1.14E-06       1     0.
  9.000    215.2      5.99E-07      494.92   126.56   1.20E-06       1     0.
 10.000    215.2      6.09E-07      543.64   134.88   1.22E-06       1     0.
 12.000    215.2      5.91E-07      639.34   149.54   1.18E-06       1     0.
 14.000    215.2      5.58E-07      733.05   163.18   1.12E-06       1     0.


 16.000    215.2      5.19E-07      825.06   175.98   1.04E-06       1     0.
 18.000    215.2      4.80E-07      915.59   188.11   9.61E-07       1     0.
 20.000    215.2      4.44E-07     1004.79   199.67   8.88E-07       1     0.
 25.000    215.2      3.66E-07     1222.94   226.54   7.32E-07       1     0.
 30.000    215.2      3.06E-07     1434.92   251.16   6.12E-07       1     0.
 35.000    215.2      2.61E-07     1642.05   271.78   5.21E-07       1     0.
 40.000    215.2      2.26E-07     1844.92   291.00   4.51E-07       1     0.
 50.000    215.2      1.75E-07     2234.47   326.21   3.50E-07       1     0.
 60.000    215.2      1.41E-07     2623.11   359.11   2.83E-07       1     0.
 70.000    215.2      1.17E-07     2996.34   387.51   2.35E-07       1     0.
 80.000    215.2      9.98E-08     3361.10   414.91   2.00E-07       1     0.
 90.000    215.2      8.62E-08     3718.45   440.69   1.72E-07       1     0.
100.000    215.2      7.56E-08     4069.22   465.11   1.51E-07       1     0.
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PTDIS

```
WIND SPEED =  5.0 M/SEC. STABILITY CLASS =  4.HEIGHT OF MIXING = 5000. METERS, AMBIENT TEMPERATURE = 290.0 DEG K.

 EMISSION  PHYSICAL  STACK GAS STACK GAS  STACK     STACK GAS  BRIGGS    HEIGHT OF  DIST OF
   RATE     HEIGHT     TEMP    VELOCITY  DIAMETER   VOL FLOW    -F-     FINAL RISE FINAL RISE
 (G/SEC)     (M)     (DEG-K)    (M/SEC)     (M)    (M**3/SEC)               (M)       (KM)

    1.00       35.0     440.0     51.60      1.00     40.50      43.10     107.1      0.515

DISTANCE EFFECTIVE CONCENTRATION SIGY        SIGZ     CHI * U / Q    MDUM   ANDUM
  KM     HEIGHT(M)     G/M**3       M.        M.        SEC/M**3

  0.500     105.7      5.44E-12      36.15     18.30    2.75E-11        1      0.
  1.000     107.1      1.11E-07      68.13     32.09    5.57E-07        1      0.
  1.500     107.1      5.71E-07      98.55     41.67    2.85E-06        1      0.
  2.000     107.1      1.02E-06     127.95     50.15    5.08E-06        1      0.
  2.500     107.1      1.27E-06     156.60     57.90    6.35E-06        1      0.
  3.000     107.1      1.37E-06     184.64     65.12    6.85E-06        1      0.
  3.500     107.1      1.37E-06     212.19     71.48    6.83E-06        1      0.
  4.000     107.1      1.32E-06     239.32     77.49    6.61E-06        1      0.
  4.500     107.1      1.26E-06     266.07     83.21    6.28E-06        1      0.
  5.000     107.1      1.18E-06     292.48     88.69    5.92E-06        1      0.
  6.000     107.1      1.04E-06     344.45     99.03    5.20E-06        1      0.
  7.000     107.1      9.12E-07     395.43    108.71    4.56E-06        1      0.
  8.000     107.1      8.02E-07     445.55    117.85    4.01E-06        1      0.
  9.000     107.1      7.11E-07     494.92    126.56    3.55E-06        1      0.
 10.000     107.1      6.34E-07     543.64    134.89    3.17E-06        1      0.
 12.000     107.1      5.15E-07     639.34    149.54    2.58E-06        1      0.
 14.000     107.1      4.29E-07     733.05    163.18    2.15E-06        1      0.
 16.000     107.1      3.64E-07     825.06    175.98    1.82E-06        1      0.
 18.000     107.1      3.14E-07     915.59    188.11    1.57E-06        1      0.
 20.000     107.1      2.75E-07    1004.79    199.67    1.37E-06        1      0.
 25.000     107.1      2.06E-07    1222.84    226.54    1.03E-06        1      0.
 30.000     107.1      1.61E-07    1434.92    251.16    8.07E-07        1      0.
 35.000     107.1      1.32E-07    1642.05    271.78    6.60E-07        1      0.
 40.000     107.1      1.11E-07    1844.92    291.00    5.54E-07        1      0.
 50.000     107.1      8.26E-08    2239.97    326.21    4.13E-07        1      0.
 60.000     107.1      6.48E-08    2623.11    358.11    3.24E-07        1      0.
 70.000     107.1      5.28E-08    2996.34    387.51    2.64E-07        1      0.
 80.000     107.1      4.42E-08    3361.10    414.91    2.21E-07        1      0.
 90.000     107.1      3.77E-08    3714.45    440.69    1.89E-07        1      0.
100.000     107.1      3.28E-08    4069.22    465.11    1.64E-07        1      0.
```

PTDIS

```
WIND SPEED =  2.0 M/SEC, STABILITY CLASS =  5,HEIGHT OF MIXING = 1000. METERS, AMBIENT TEMPERATURE = 290.0 DEG K.

 EMISSION  PHYSICAL   STACK GAS STACK GAS  STACK     STACK GAS  BRIGGS   HEIGHT OF  DIST OF
   RATE     HEIGHT      TEMP    VELOCITY  DIAMETER   VOL FLOW    -F-    FINAL RISE FINAL RISE
 (G/SEC)     (M)      (DEG-K)   (M/SEC)     (M)     (M**3/SEC)             (M)        (KM)


    1.00      35.0      440.0     51.60      1.00      40.50     43.10     111.1      0.242

DISTANCE EFFECTIVE CONCENTRATION SIGY        SIGZ     CHI * U / Q   HOUM  ANDUM
   KM    HEIGHT(M)     G/M**3)     M.         M.       SEC/M**3)

   0.500    111.1      2.05E-20      27.02     12.80   4.10E-20       1     0.
   1.000    111.1      2.70E-10      50.94     21.63   5.40E-10       1     0.
   1.500    111.1      2.84E-08      73.70     27.93   5.68E-08       1     0.
   2.000    111.1      2.03E-07      95.70     33.49   4.05E-07       1     0.
   2.500    111.1      5.03E-07     117.14     38.94   1.01E-06       1     0.
   3.000    111.1      8.57E-07     138.13     42.22   1.71E-06       1     0.
   3.500    111.1      1.19E-06     158.75     46.11   2.39E-06       1     0.
   4.000    111.1      1.48E-06     179.06     49.77   2.96E-06       1     0.
   4.500    111.1      1.66E-06     199.08     52.82   3.32E-06       1     0.
   5.000    111.1      1.79E-06     218.86     55.71   3.58E-06       1     0.
   6.000    111.1      1.94E-06     257.77     61.08   3.87E-06       1     0.
   7.000    111.1      1.98E-06     295.94     66.03   3.96E-06       1     0.
   8.000    111.1      1.96E-06     333.47     70.64   3.92E-06       1     0.
   9.000    111.1      1.91E-06     370.44     74.97   3.82E-06       1     0.
  10.000    111.1      1.84E-06     406.92     79.07   3.69E-06       1     0.
  12.000    111.1      1.68E-06     478.59     86.10   3.36E-06       1     0.
  14.000    111.1      1.52E-06     548.78     92.53   3.05E-06       1     0.
  16.000    111.1      1.39E-06     617.70     98.48   2.77E-06       1     0.
  18.000    111.1      1.26E-06     685.50    104.05   2.52E-06       1     0.
  20.000    111.1      1.15E-06     752.32    109.30   2.31E-06       1     0.
  25.000    111.1      9.45E-07     915.66    118.87   1.89E-06       1     0.
  30.000    111.1      7.95E-07    1074.94    127.31   1.59E-06       1     0.
  35.000    111.1      6.84E-07    1229.71    134.91   1.37E-06       1     0.
  40.000    111.1      5.99E-07    1381.72    141.86   1.20E-06       1     0.
  50.000    111.1      4.79E-07    1677.72    151.54   9.57E-07       1     0.
  60.000    111.1      3.98E-07    1966.91    159.96   7.96E-07       1     0.
  70.000    111.1      3.40E-07    2244.49    167.41   6.80E-07       1     0.
  80.000    111.1      2.96E-07    2517.83    174.15   5.92E-07       1     0.
  90.000    111.1      2.62E-07    2785.64    180.33   5.24E-07       1     0.
 100.000    111.1      2.35E-07    3048.52    186.04   4.70E-07       1     0.
```

Terrain Interaction Modeling

$$\bar{C}/Q = \frac{2.03}{\sigma_z \bar{u} x} \exp\left[-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2\right]$$

Where:

$\bar{C}$ = time average (1 hour) concentration in grams/m^3

Q = source strength in grams/sec (in this case 1 gm/sec)

σ_z = standard deviation of vertical plume diffusion in meters

$\bar{u}$ = mean transport wind speed m/sec

x = downwind distance to receptor, meters

h = height of plume centerline above receptor (calculated by $h = H - z$ where H is the effective plume height and z is the elevation of the receptor. Note: minimum allowable value for h is 10 meters.

For the purpose of this study, Stability E with a wind speed of 2.5 m/sec was used. Under these conditions the effective plume height H = 105 meters.

RELATIVE CONCENTRATIONS FOR TERRAIN INTERACTION MODELING

SITE	DISTANCE X	EVEVATION Z	DIRECTION	$\overline{C}/Q$
Port Angeles	2700	70	SW	5.1272×10^{-6}
	3400	92	SW	4.9886×10^{-6}
	3800	100	SW	4.3562×10^{-6}
	4300	105	SW,S,SSE	3.5650×10^{-6}
Burrows Bay	800	82	SW	2.4926×10^{-5}
	900	75	NNW	1.4645×10^{-5}
	1000	105	NNW	3.3895×10^{-5}
	2500	75	NE	6.1952×10^{-6}
	2800	105	NE	6.8658×10^{-6}
March Point	2400	89	NNE	8.1482×10^{-6}
	2400	61	S	4.5543×10^{-6}
	3200	61	WNW	3.4978×10^{-6}
	4000	105	SW	3.9796×10^{-6}
	4800	61	W	2.2477×10^{-6}
Cherry Point	2000	30	E	1.0481×10^{-6}
	2100	60	ESE	4.8340×10^{-6}
	2800	45	NNW	2.4242×10^{-6}
	3200	65	E	3.8149×10^{-6}

Volume Source Modeling

$$\bar{C}/Q = \left[(\pi \sigma_y \sigma_z + CA)\bar{u} \right]^{-1}$$

Where:

$\bar{C}$ = time average (1 hour) concentration in grams/m^3

Q = source strength in grams/sec (in this case 1 gm/sec)

σ_y = standard deviation of crosswind plume diffusion in meters

σ_z = standard deviation of vertical plume diffusion in meters

C = fraction of area over which the plume is dispersed by the wake (a conservative value is 0.5) dimensionless

A = cross sectional area of obstacle normal to the flow

$\bar{u}$ = mean transport wind speed m/sec

Input Parameters

Storage Tanks

Tank Height	19.8 m
Tank Diameter	82.3 m
Tank Farm Length (Square Formation)	600 m
Tank Farm Length (In-line Formation)	1850 m
Average Spacing of Tanks	1 tank/0.028 km^2

Tankers

Average Tanker Length	270 m
Average Tanker Deck Cross-Section Width	42 m
Average Tanker Deck Height Above Water	17 m
Length of 4-Berth In-Line Formation	1200 m
Length of 4-Berth Grouped Formation	580 m
Width of 4-Berth Grouped Formation	120 m

RELATIVE CONCENTRATIONS FOR

A VOLUME SOURCE

	0.5 km	1.0 km	5.0 km	10.0 km
Stability B Wind Speed 2 m/sec				
- Tank Farm -				
in-line along wind	3.3440×10^{-5}	9.2213×10^{-6}	3.9763×10^{-7}	
in-line across wind	1.5407×10^{-5}	6.9714×10^{-6}	3.9217×10^{-7}	
clustered formation	2.4904×10^{-5}	8.4250×10^{-6}	3.9602×10^{-7}	
- Tankers -				
in-line along wind	3.4497×10^{-5}	9.2999×10^{-6}	3.9777×10^{-7}	
in-line across wind	2.0545×10^{-5}	7.8608×10^{-6}	3.9468×10^{-7}	
grouped along wind	3.2988×10^{-5}	9.1866×10^{-6}	3.9756×10^{-7}	
grouped across wind	2.6223×10^{-5}	8.5709×10^{-6}	3.9633×10^{-7}	

RELATIVE CONCENTRATIONS FOR
A VOLUME SOURCE

	0.5 km	1.0 km	5.0 km	10.0 km
Stability B Wind Speed 4 m/sec				
- Tank Farm -				
in-line along wind	1.6720×10^{-5}	4.6106×10^{-6}	1.9882×10^{-7}	---
in-line across wind	7.7036×10^{-6}	3.4857×10^{-6}	1.9608×10^{-7}	---
clustered formation	1.2452×10^{-5}	4.2125×10^{-6}	1.9801×10^{-7}	--- ---
- Tankers-				
in-line along wind	1.7248×10^{-5}	4.6500×10^{-6}	1.9888×10^{-7}	---
in-line across wind	1.0272×10^{-5}	3.9304×10^{-6}	1.9734×10^{-7}	---
grouped along wind	1.6494×10^{-5}	4.5933×10^{-6}	1.9878×10^{-7}	---
grouped across wind	1.3112×10^{-5}	4.6500×10^{-6}	1.9816×10^{-7}	---
Stability C Wind Speed 3 m/sec				
- Tank Farm -				
in-line along wind	5.1521×10^{-5}	1.5933×10^{-5}	1.0427×10^{-6}	2.6509×10^{-7}
in-line across wind	1.3906×10^{-5}	8.6758×10^{-6}	9.8857×10^{-7}	2.6145×10^{-7}
clustered formation	2.8748×10^{-5}	1.2798×10^{-5}	1.0262×10^{-6}	2.6401×10^{-7}
- Tankers -				
in-line along wind	5.5446×10^{-5}	1.6289×10^{-5}	1.0442×10^{-6}	2.6518×10^{-7}
in-line across wind	2.1024×10^{-5}	1.0999×10^{-5}	1.0130×10^{-6}	2.6312×10^{-7}
grouped along wind	4.9939×10^{-5}	1.5778×10^{-5}	1.0420×10^{-6}	2.6504×10^{-7}
grouped across wind	3.1492×10^{-5}	1.3314×10^{-5}	1.0294×10^{-6}	2.6422×10^{-7}

RELATIVE CONCENTRATIONS FOR
A VOLUME SOURCE

	0.5 km	1.0 km	5.0 km	10.0 km
Stability C Wind Speed 5 m/sec				
- Tanker Farm -				
in-line along wind	3.0912×10^{-5}	9.5597×10^{-6}	6.2561×10^{-7}	1.5905×10^{-7}
in-line across wind	8.3438×10^{-6}	5.2045×10^{-6}	5.9314×10^{-7}	---
clustered formation	1.7249×10^{-5}	7.6787×10^{-6}	6.1574×10^{-7}	---
- Tankers -				
in-line along wind	3.3268×10^{-5}	9.7736×10^{-6}	6.2651×10^{-7}	1.5911×10^{-7}
in-line across wind	1.2614×10^{-5}	6.5993×10^{-6}	6.0777×10^{-7}	---
grouped along wind	2.9963×10^{-5}	9.4669×10^{-6}	6.2521×10^{-7}	---
grouped across wind	1.8895×10^{-5}	7.9884×10^{-6}	6.1766×10^{-7}	---
Stability C Wind Speed 10 m/sec				
- Tanker Farm -				
in-line along wind	1.5456×10^{-5}	4.7798×10^{-6}	3.1280×10^{-7}	7.9525×10^{-8}
in-line across wind	4.1719×10^{-6}	2.6022×10^{-6}	2.9657×10^{-7}	---
clustered formation	8.6245×10^{-6}	3.8394×10^{-6}	3.0787×10^{-7}	---
- Tankers -				
in-line along wind	1.6634×10^{-5}	4.8868×10^{-6}	3.1326×10^{-7}	7.9555×10^{-8}
in-line across wind	6.3070×10^{-6}	3.2996×10^{-6}	3.0388×10^{-7}	---
grouped along wind	1.4982×10^{-5}	4.7334×10^{-6}	3.1260×10^{-7}	---
grouped across wind	9.4475×10^{-6}	3.9942×10^{-6}	3.0883×10^{-7}	---

RELATIVE CONCENTRATIONS FOR
A VOLUME SOURCE

	0.5 km	1.0 km	5.0 km	10.0 km
Stability D Wind Speed 3 m/sec				
- Tank Farm -				
in-line along wind	1.1416×10^{-4}	4.4037×10^{-5}	3.9651×10^{-6}	1.4684×10^{-6}
in-line across wind	1.6324×10^{-5}	1.3296×10^{-5}	3.2819×10^{-6}	1.3633×10^{-6}
clustered formation	4.1434×10^{-5}	2.6258×10^{-5}	3.7372×10^{-6}	1.4359×10^{-6}
- Tankers -				
in-line along wind	1.3540×10^{-4}	4.6873×10^{-5}	3.9868×10^{-6}	1.4713×10^{-6}
in-line across wind	2.7090×10^{-5}	1.9661×10^{-5}	3.5669×10^{-6}	1.4101×10^{-6}
grouped along wind	1.0667×10^{-4}	4.2876×10^{-5}	3.9554×10^{-6}	1.4670×10^{-6}
grouped across wind	4.7383×10^{-5}	2.8528×10^{-5}	3.7801×10^{-6}	1.4422×10^{-6}
Stability D Wind Speed 5 m/sec				
- Tank Farm -				
in-line along wind	6.8496×10^{-5}	2.6422×10^{-5}	2.3790×10^{-6}	8.8102×10^{-7}
in-line across wind	9.7944×10^{-6}	7.9778×10^{-6}	1.9691×10^{-6}	8.1796×10^{-7}
clustered formation	2.4861×10^{-5}	1.5755×10^{-5}	2.2423×10^{-6}	8.6160×10^{-7}
- Tankers -				
in-line along wind	8.1239×10^{-5}	2.8124×10^{-5}	2.3921×10^{-6}	8.8280×10^{-7}
in-line across wind	1.6254×10^{-5}	1.1796×10^{-5}	2.1401×10^{-6}	8.4604×10^{-7}
grouped along wind	6.4003×10^{-5}	2.5725×10^{-5}	2.3733×10^{-6}	8.8022×10^{-7}
grouped across wind	2.8430×10^{-5}	1.7117×10^{-5}	2.2680×10^{-6}	8.6533×10^{-7}

RELATIVE CONCENTRATIONS FOR
A VOLUME SOURCE

	0.5 km	1.0 km	5.0 km	10.0 km
Stability D Wind Speed 10 m/sec				
- Tank Farm -				
in-line along wind	3.4248×10^{-5}	1.3211×10^{-5}	1.1895×10^{-6}	4.4051×10^{-7}
in-line across wind	4.8972×10^{-6}	$\times 10^{-6}$	9.8455×10^{-7}	4.0898×10^{-7}
clustered formation	1.2430×10^{-5}	7.8775×10^{-6}	1.1212×10^{-6}	4.3080×10^{-7}
- Tankers -				
in-line along wind	4.0620×10^{-5}	1.4062×10^{-5}	1.1960×10^{-6}	4.4140×10^{-7}
in-line across wind	8.1270×10^{-6}	5.8980×10^{-6}	1.0700×10^{-6}	4.2302×10^{-7}
grouped along wind	3.2002×10^{-5}	1.2862×10^{-5}	1.1866×10^{-6}	4.4011×10^{-7}
grouped across wind	1.4215×10^{-5}	8.5585×10^{-6}	1.1340×10^{-6}	4.3267×10^{-7}
Stability D Wind Speed 20 m/sec				
- Tank Farm -				
in-line along wind	1.7124×10^{-5}	6.6055×10^{-6}	5.9475×10^{-7}	2.2026×10^{-7}
in-line across wind	2.4486×10^{-6}	1.9944×10^{-6}	4.9228×10^{-7}	2.0449×10^{-7}
clustered formation	6.2152×10^{-6}	3.9388×10^{-6}	5.6058×10^{-7}	2.1540×10^{-7}
- Tankers -				
in-line along wind	2.0310×10^{-5}	7.0310×10^{-6}	5.9802×10^{-7}	2.2070×10^{-7}
in-line across wind	4.0635×10^{-6}	2.9490×10^{-6}	5.3502×10^{-7}	2.1151×10^{-7}
grouped along wind	1.6001×10^{-5}	6.4312×10^{-6}	5.9332×10^{-7}	2.2006×10^{-7}
grouped across wind	7.1075×10^{-6}	4.2792×10^{-6}	5.6700×10^{-7}	2.1633×10^{-7}

RELATIVE CONCENTRATIONS FOR
A VOLUME SOURCE

	0.5 km	1.0 km	5.0 km	10.0 km
Stability E Wind Speed 2.5 m/sec				
- Tank Farm -				
in-line along wind	2.0391×10^{-4}	9.2302×10^{-5}	9.9788×10^{-6}	3.5115×10^{-6}
in-line across wind	2.0553×10^{-5}	1.8320×10^{-5}	6.9463×10^{-6}	3.0439×10^{-6}
clustered formation	5.6444×10^{-5}	4.2290×10^{-5}	8.8476×10^{-6}	3.3603×10^{-6}
- Tankers -				
in-line along wind	2.6601×10^{-4}	1.0321×10^{-4}	1.0094×10^{-5}	3.5256×10^{-6}
in-line across wind	3.5253×10^{-5}	2.9158×10^{-5}	8.0857×10^{-6}	3.2442×10^{-6}
grouped along wind	1.8461×10^{-4}	8.8133×10^{-5}	9.9280×10^{-6}	3.5052×10^{-6}
grouped across wind	6.5825×10^{-5}	4.7345×10^{-5}	9.0498×10^{-6}	3.3890×10^{-6}
Stability E Wind Speed 4 m/sec				
- Tank Farm -				
in-line along wind	1.2744×10^{-4}	5.7689×10^{-5}	6.2368×10^{-6}	2.1947×10^{-6}
in-line across wind	1.2846×10^{-5}	1.1450×10^{-5}	4.3414×10^{-6}	1.9024×10^{-6}
clustered formation	3.5277×10^{-5}	2.6431×10^{-5}	5.5298×10^{-6}	2.1002×10^{-6}
- Tankers -				
in-line along wind	1.6626×10^{-4}	6.4506×10^{-5}	6.3088×10^{-6}	2.2035×10^{-6}
in-line across wind	2.2033×10^{-5}	6.4506×10^{-5}	5.0536×10^{-6}	2.0276×10^{-6}
grouped along wind	1.1538×10^{-4}	5.5083×10^{-5}	6.2050×10^{-6}	2.1907×10^{-6}
grouped across wind	4.1141×10^{-5}	2.9591×10^{-5}	5.6561×10^{-6}	2.1182×10^{-6}

TABLE A

AVERAGE HOURLY EMISSION RATES GM/SEC
(FROM TABLE 15)

POLLUTANT	SCENARIO I	SUB-SCENARIO	SCENARIO II	SUB-SCENARIO
	INLAND	IA	INLAND	IIA
SO_2	48.9	63.1	70.8	92.0
NO_x	22.9	29.4	32.9	43.2
PART	5.5	7.1	8.0	10.3
HC	1.8	2.1	2.4	3.2
CO	0.9	1.1	1.2	1.6
HCHO	0.5	0.6	0.7	0.9
ORGANIC ACIDS	0.3	0.3	0.3	0.4
FUGITIVE HC	179* 96+	54 34	226 123	59 40
FUGITIVE HC EXCLUDING PURGING & BALLASTING	2.9	13.0	5.6	18.3

TABLE B

SHORT TERM WORST CASE EMISSIONS GM/SEC
(FROM TABLE 16)

POLLUTANT	SCENARIO I	SUB-SCENARIO	SCENARIO II	SUB-SCENARIO
	INLAND	IA	INLAND	IIA
SO_2	159.4	169.8	199.5	209.2
NO_x	69.2	73.7	86.6	90.7
PART	15.2	16.3	19.2	20.0
HC	2.1	2.3	2.6	2.8
CO	1.4	1.4	1.6	1.8
HCHO	1.4	1.4	1.6	1.8
ORGANIC ACIDS	-----	-----	-----	-----
FUGITIVE HC	1063* 854+ (972)* (542)+	2090* 1557+ (1850)* (874)+	1063* 854+ (972)* (542)+	2090* 1557+ (1850)* (874)+
FUGITIVE HC EXCLUDING PURGING & BALLASTING	45.4	90.7	49.1	90.7

TABLE C

24-HOUR WORST CASE EMISSION RATE GM/SEC

(FROM TABLE 17)

POLLUTANT	SCENARIO I INLAND	SUB-SCENARIO IA	SCENARIO II INLAND	SUB-SCENARIO IIA
SO_2	139.5	150.9	169.5	174.8
NO_x	62.5	67.4	76.3	79.3
PART	14.4	15.5	17.7	18.4
HC	3.2	3.3	4.1	4.3
CO	1.7	1.8	2.2	2.3
HCHO	1.2	1.3	1.5	1.6
ORGANIC ACIDS	0.3	0.3	0.4	0.4
FUGITIVE HC	908* 479+	463* 258+	908* 479+	470* 265+
FUGITIVE HC EXCLUDING PURGING & BALLASTING	26.5	59.3	26.5	66.6

TABLE D

BALLASTING EMISSIONS
(FROM TABLE 9)

TANKER SIZE	LBS/HR	GM/SEC
130,000	4152	523
120,000	3332	420
80,000	2555	322
76,000	1851	233
70,000	1682	212
62,000	1526	192
53,000	1366	172
52,000	1332	168
50,000	1245	157
49,000	1212	153

TABLE E

TANK FARM EMISSIONS

	LBS/HR		GM/SEC	
WIND SPEED M/SEC	SCENARIO I	SCENARIO II	SCENARIO I	SCENARIO II
2	114.7	156.4	14.5	19.7
2.5	131.9	179.9	16.6	22.7
3	148.L	202.0	18.7	25.5
4	178.3	243.2	22.5	30.6
5	206.3	281.3	26.0	35.4
10	327.1	336.1	41.2	56.2
20	523.4	713.7	65.9	89.9